PB83-258103

Draft Environmental Impact Statement Nonmetallic Mineral Processing Plants Background Information for Proposed Standards

(U.S.) Environmental Protection Agency
Research Triangle Park, NC

Apr 83

U.S. Department of Commerce
National Technical Information Service
NTIS

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO.
EPA-450/3-83-001a

2.

3. RECIPIENT'S ACCESSION NO.
PB83 258103

4. TITLE AND SUBTITLE
Nonmetallic Mineral Processing Plants -
Background Information for Proposed Standards

5. REPORT DATE
April 1983

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Office of Air Quality Planning and Standards
U.S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711

10. PROGRAM ELEMENT NO.

11. CONTRACT/GRANT NO.

12. SPONSORING AGENCY NAME AND ADDRESS
DAA for Air Quality Planning and Standards
Office of Air, Noise, and Radiation
U.S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711

13. TYPE OF REPORT AND PERIOD COVERED

14. SPONSORING AGENCY CODE
EPA/200/04

16. ABSTRACT

Standards of performance for the control of emissions from nonmetallic mineral processing plants are being proposed under the authority of Section 111 of the Clean Air Act. These standards would apply to new, modified, or reconstructed facilities at any nonmetallic mineral processing plant including crushers, grinding mills, screens, bucket elevators, conveyor belt transfer points, bagging operations, storage bins, and enclosed truck and railcar loading stations. This document contains background information and environmental and economic impact assessments, as proposed under 40 CFR Part 60, Subpart OOO.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air pollution Pollution control Standards of performance Nonmetallic mineral processing plants Particulate emissions	Air Pollution Control	13B

18. DISTRIBUTION STATEMENT
Unlimited

19. SECURITY CLASS (This Report)
Unclassified

20. SECURITY CLASS (This page)
Unclassified

21. NO. OF PAGES
485

22. PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

United States
Environmental Protection
Agency

Office of Air Quality
Planning and Standards
Research Triangle Park NC 27711

EPA-450/3-83-001a
April 1983

Air

PB83-258103

EPA

Nonmetallic Mineral Processing Plants— Background Information for Proposed Standards

Draft EIS

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

EPA-450/3-83-001a

Nonmetallic Mineral Processing Plants— Background Information for Proposed Standards

Emission Standards and Engineering Division

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air, Noise, and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

April 1983

This report has been reviewed by the Emission Standards and Engineering Division of The Office of Air Quality Planning and Standards, EPA, and approved for publication. Mention of trade names or commercial products is not intended to constitute endorsement or recommendation for use. Copies of this report are available through the Library Services Office (MD-35), U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711; or, for a fee, from the National Technical Information Services, 5285 Port Royal Road, Springfield, Virginia 22161.

ENVIRONMENTAL PROTECTION AGENCY

Background Information
and Draft
Environmental Impact Statement
Nonmetallic Mineral
Processing Plants

Prepared by:

Don R Goodwin 11/23/82

Don R. Goodwin (Date)
Director, Emission Standards and Engineering Division
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

1. The proposed standards of performance would limit emissions of particulate matter from new, modified, and reconstructed nonmetallic mineral processing plants. Section 111 of the Clean Air Act (42 U.S.C. 7411), as amended, directs the Administrator to establish standards of performance for any category of new stationary source of air pollution that ". . . causes or contributes significantly to air pollution which may reasonably be anticipated to endanger public health or welfare."

2. Copies of this document have been sent to the following Federal Departments: Labor, Health and Human Services, Defense, Transportation, Agriculture, Commerce, Interior, and Energy, as well as the National Science Foundation, the Council on Environmental Quality, State and Territorial Air Pollution Program Administrators, the Association of Local Air Pollution Control Officials, EPA Regional Administrators, and other interested parties.

3. The comment period for review of this document is 60 days. Mr. Gene Smith may be contacted regarding the date of the comment period.

4. For additional information contact:

   Mr. Gene Smith
   Standards Development Branch (MD-13)
   U.S. Environmental Protection Agency
   Research Triangle Park, NC 27711
   telephone: (919) 541-5624

5. Copies of this document may be obtained from:

   U.S. EPA Library (MD-35)
   Research Triangle Park, NC 27711

   National Technical Information Service
   5886 Port Royal Road
   Springfield, VA 22161

TABLE OF CONTENTS

Page

LIST OF FIGURES. viii

LIST OF TABLES x

CHAPTER 1. SUMMARY. 1-1

1.1 PROPOSED STANDARDS 1-1

1.2 ENVIRONMENTAL IMPACT 1-2

1.3 ECONOMIC IMPACT. 1-5

CHAPTER 2. INTRODUCTION 2-1

2.1 AUTHORITY FOR THE STANDARDS. 2-1

2.2 SELECTION OF CATEGORIES OF STATIONARY SOURCES. 2-6

2.3 PROCEDURE FOR DEVELOPMENT OF STANDARDS OF PERFORMANCE. 2-8

2.4 CONSIDERATION OF COSTS 2-11

2.5 CONSIDERATION OF ENVIRONMENTAL IMPACTS 2-12

2.6 IMPACT ON EXISTING SOURCES 2-14

2.7 REVISION OF STANDARDS OF PERFORMANCE 2-15

CHAPTER 3. THE NON-METALLIC MINERALS INDUSTRY 3-1

3.1 GENERAL. 3-1

3.2 NON-METALLIC MINERALS PREPARATION PROCESSES AND THEIR EMISSIONS. 3-12

3.3 REFERENCES 3-52

CHAPTER 4. EMISSION CONTROL TECHNIQUES. 4-1

4.1 CONTROL OF PLANT PROCESS OPERATIONS. 4-1

4.2 FACTORS AFFECTING THE PERFORMANCE OF CONTROL METHODS 4-29

4.3 PERFORMANCE OF PARTICULATE EMISSION CONTROL TECHNIQUES 4-32

4.4 REFERENCES 4-59

TABLE OF CONTENTS (continued)

Page
CHAPTER 5. MODIFICATION AND RECONSTRUCTION. 5-1
5.1 MODIFICATION 5-1
5.2 RECONSTRUCTION 5-2
CHAPTER 6. EMISSION CONTROL SYSTEMS 6-1
CHAPTER 7. ENVIRONMENTAL IMPACT 7-1
7.1 AIR POLLUTION IMPACT 7-1
7.2 WATER POLLUTION IMPACT 7-18
7.3 SOLID WASTE DISPOSAL IMPACT. 7-18
7.4 ENERGY IMPACT. 7-19
7.5 NOISE IMPACT 7-23
7.6 REFERENCES 7-25
CHAPTER 8. ECONOMIC IMPACT. 8-1
8.0 SUMMARY. 8-1
8.1 UNITED STATED NON-METALLIC MINERALS INDUSTRY STRUCTURE 8-4
8.2 COST ANALYSIS OF ALTERNATIVE EMISSION CONTROL SYSTEMS. 8-52
8.3 OTHER COST CONSIDERATIONS. 8-84
8.4 ECONOMIC IMPACT ASSESSMENT 8-88
8.5 POTENTIAL SOCIO-ECONOMIC AND INFLATIONARY IMPACTS. 8-117
APPENDIX A. EVOLUTION OF THE PROPOSED STANDARDS A-1
APPENDIX B. INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS. B-1
APPENDIX C. SUMMARY OF TEST DATA. C-1
APPENDIX D. EMISSION MEASUREMENT AND CONTINUOUS MONITORING. D-1
D.1 EMISSION MEASUREMENT METHODS D-1
D.2 MONITORING SYSTEMS AND DEVICES D-2
D.3 PERFORMANCE TEST METHODS D-2

TABLE OF CONTENTS (continued)

Page

SUPPLEMENT A. ECONOMIC IMPACT ANALYSIS FOR PORTABLE PLANTS S-1

A.0 INTRODUCTION AND SUMMARY S-1

A.1 INDUSTRY CHARACTERIZATION S-3

A.2 COST ANALYSIS S-8

A.3 ECONOMIC IMPACTS S-30

LIST OF FIGURES

Page

Figure 3-1 FLOWSHEET OF A TYPICAL CRUSHING PLANT 3-13

Figure 3-2 GENERAL SCHEMATIC FOR NON-METALLIC MINERALS PROCESSING . . 3-17

Figure 3-3 DOUBLE-TOGGLE JAW CRUSHER 3-25

Figure 3-4 SINGLE-TOGGLE JAW CRUSHER 3-25

Figure 3-5 THE PIVOTED SPINDLE GYRATORY 3-28

Figure 3-6 CONE CRUSHER 3-29

Figure 3-7 DOUBLE-ROLL CRUSHER 3-30

Figure 3-8 SINGLE ROLL CRUSHER 3-31

Figure 3-9 HAMMERMILL 3-32

Figure 3-10 IMPACT CRUSHER 3-33

Figure 3-11 VIBRATING GRIZZLY 3-36

Figure 3-12 VIBRATING SCREEN 3-37

Figure 3-13 CONVEYOR BELT TRANSFER POINT 3-40

Figure 3-14 BUCKET ELEVATOR TYPES 3-41

Figure 3-15 ROLLER MILL 3-46

Figure 3-16 BALL MILL 3-48

Figure 3-17 FLUID-ENERGY MILL 3-48

Figure 4-1 WET DUST SUPPRESSION SYSTEM 4-7

Figure 4-2 DUST SUPPRESSION APPLICATION AT CRUSHER DISCHARGE 4-9

Figure 4-3 HOOD CONFIGURATION USED TO CONTROL A CONE CRUSHER 4-14

Figure 4-4 HOOD CONFIGURATION FOR VIBRATING SCREEN 4-15

Figure 4-5 HOOD CONFIGURATION FOR CONVEYOR TRANSFER, LESS THAN 0.91 METER (3-FOOT) FALL 4-17

Figure 4-6 HOOD CONFIGURATION FOR A CHUTE TO BELT OR CONVEYOR TRANSFER, GREATER THAN 0.01 METERS (3-FOOT) FALL 4-18

LIST OF TABLES (continued)

Page

Table 6-2 LIST OF PROCESS EQUIPMENT INCLUDING ENERGY REQUIREMENTS AND AIR VOLUME REQUIREMENTS USED IN DETERMINING MODEL PLANTS. 6-4

Table 6-3 PLANT SIZES FOR THE VARIOUS NON-METALLIC MINERALS INDUSTRIES (METRIC UNITS) 6-6

Table 7-1 ALLOWABLE EMISSIONS UNDER GENERAL STATE PROCESS WEIGHT REGULATIONS. 7-2

Table 7-2 GROWTH RATES AND MINERAL PRODUCTION LEVELS FOR THE VARIOUS NON-METALLIC MINERALS INDUSTRIES. 7-3

Table 7-3 SUMMARY OF AIR POLLUTION IMPACT 7-5

Table 7-4 STACK AND EMISSIONS DATA. 7-11

Table 7-5 ESTIMATED MAXIMUM 24-HOUR AND ANNUAL GROUND-LEVEL PARTICULATE CONCENTRATION DUE TO EMISSIONS FROM THE PROCESS SOURCES IN THE MODEL NON-METALLIC MINERALS PLANTS HAVING BOTH CRUSHING AND GRINDING OPERATIONS . . 7-15

Table 7-6 ESTIMATED MAXIMUM 24-HOUR AND ANNUAL GROUND-LEVEL PARTICULATE CONCENTRATION DUE TO EMISSIONS FROM THE PROCESS SOURCES IN THE MODEL NON-METALLIC MINERALS PLANTS HAVING ONLY CRUSHING OPERATIONS. 7-16

Table 7-7 ENERGY REQUIREMENTS FOR MODEL NON-METALLIC MINERALS PLANTS HAVING CRUSHING AND GRINDING OPERATIONS. 7-21

Table 7-8 ENERGY REQUIREMENTS FOR MODEL NON-METALLIC MINERALS PLANTS HAVING CRUSHING OPERATIONS ONLY. 7-21

Table 7-9 ENERGY IMPACT ON INDIVIDUAL NON-METALLIC INDUSTRIES UNDER PROPOSED NSPS 7-24

Table 8-1 SAND AND GRAVEL: SALIENT STATISTICS. 8-9

Table 8-2 U.S. CRUSHED STONE INDUSTRY 8-12

Table 8-3 U.S. GYPSUM INDUSTRY. 8-16

Table 8-4 U.S. DIATOMITE INDUSTRY 8-18

Table 8-5 U.S. PERLITE INDUSTRY 8-20

Table 8-6 U.S. PUMICE INDUSTRY. 8-22

LIST OF TABLES (continued)

Page

Table 8-7 U.S. VERMICULITE INDUSTRY 8-24

Table 8-8 U.S. MICA INDUSTRY. 8-26

Table 8-9 U.S. BARITE INDUSTRY. 8-29

Table 8-10 U.S FLUORSPAR INDUSTRY. 8-31

Table 8-11 U.S. SALT INDUSTRY. 8-33

Table 8-12 U.S. BORON INDUSTRY 8-35

Table 8-13 U.S. SODIUM CARBONATE INDUSTRY. 8-37

Table 8-14 U.S. SODIUM SULFATE INDUSTRY. 8-38

Table 8-15 U.S. CLAY INDUSTRY. 8-41

Table 8-16 U.S. FELDSPAR INDUSTRY. 8-44

Table 8-17 U.S. KYANITE INDUSTRY 8-45

Table 8-18 U.S. TALC INDUSTRY. 8-48

Table 8-19 TECHNICAL PARAMETERS USED IN DEVELOPING CONTROL SYSTEM COSTS. 8-54

Table 8-20 ANNUALIZED COST PARAMETERS. 8-57

Table 8-21 FABRIC FILTER COSTS FOR NEW MODEL PLANT 1: 9.1 mg/Hour. 8-59

Table 8-22 FABRIC FILTER COSTS FOR NEW MODEL PLANT 1: 23 Mg/Hour . 8-60

Table 8-23 FABRIC FILTER COSTS FOR NEW MODEL PLANT 1: 68 Mg/Hour . 8-61

Table 8-24 FABRIC FILTER COSTS FOR NEW MODEL PLANT 1: 135 Mg/Hour. 8-62

Table 8-25 FABRIC FILTER COSTS FOR NEW MODEL PLANT 1: 270 Mg/Hour. 8-63

Table 8-26 FABRIC FILTER COSTS FOR NEW MODEL PLANT 1: 540 Mg/Hour. 8-64

Table 8-27 FARBIC FILTER COSTS FOR NEW MODEL PLANT 2: 9.1 Mg/Hour. 8-65

Table 8-28 FABRIC FILTER COSTS FOR NEW MODEL PLANT 2: 23 Mg/Hour . 8-66

Table 8-29 FABRIC FILTER COSTS FOR NEW MODEL PLANT 2: 68 Mg/Hour . 8-67

LIST OF FIGURES (continued)

Page

Figure 4-7 EXHAUST CONFIGURATION AT BIN OR HOPPER 4-19

Figure 4-8 BAG FILLING VENT SYSTEM. 4-20

Figure 4-9 TYPICAL BAGHOUSE OPERATION 4-23

Figure 4-10 BAGHOUSE CLEANING METHODS. 4-25

Figure 4-11 MECHANICAL, CENTRIFUGAL SCRUBBER 4-28

Figure 4-12 TYPICAL COMBINATION DUST CONTROL SYSTEMS 4-30

Figure 4-13 PARTICULATE EMISSIONS FROM NON-METALLIC MINERALS PROCESSING OPERATIONS. 4-35

Figure 4-14 PARTICULATE EMISSIONS FROM METALLIC MINERAL PROCESSING OPERATIONS 4-43

Figure 4-15 SUMMARY OF VISIBLE EMISSION MEASUREMENTS FROM BEST CONTROLLED FUGITIVE PRIMARY CRUSHING SOURCES (PORTABLE-FACILITY T) BY MEANS OF WET SUPPRESSION (ACCORDING TO EPA METHOD 9). 4-53

Figure 4-16 SUMMARY OF VISIBLE EMISSION MEASUREMENTS FROM BEST CONTROLLED FUGITIVE SECONDARY CRUSHING SOURCE (PORTABLE-FACILITY R) BY MEANS OF WET SUPPRESSION (ACCORDING TO EPA METHOD 9). 4-54

Figure 4-17 SUMMARY OF VISIBLE EMISSION MEASUREMENTS FROM BEST CONTROLLED FUGITIVE PRIMARY CRUSHING SOURCE (STATIONARY-FACILITY S) BY MEANS OF WET SUPPRESSION (ACCORDING TO EPA METHOD 9). 4-55

Figure 4-18 SUMMARY OF VISIBLE EMISSION MEASUREMENT FROM BEST CONTROLLED FUGITIVE SECONDARY CRUSHER (SMALL, STATIONARY-FACILITY S) BY MEANS OF WET SUPPRESSION (ACCORDING TO EPA METHOD 9). 4-56

Figure 4-19 SUMMARY OF VISIBLE EMISSION MEASUREMENTS FROM BEST CONTROLLED FUGITIVE SECONDARY CRUSHING SOURCE (LARGE, SECONDARY-FACILITY S) BY MEANS OF WET SUPPRESSION (ACCORDING TO EPA METHOD 9). 4-57

Figure 7-1 PLANT LAYOUTS SHOWING THE NUMBER AND LOCATIONS OF THE SOURCES (STACKS) SPECIFIED FOR EACH PLANT SIZE). 7-9

Figure 8-1 COST-EFFECTIVENESS OF ALTERNATE CONTROL SYSTEMS. 8-79

Figure 8-2 INSTALLED COSTS OF FABRIC FILTER SYSTEMS 8-81

LIST OF TABLES

Page

Table 1-1 MATRIX OF ENVIRONMENTAL AND ECONOMIC IMPACTS OF ALTERNATIVE STANDARDS 1-3

Table 3-1 INDUSTRY CHARACTERISTICS. 3-3

Table 3-2 MAJOR USES OF THE NON-METALLIC MINERALS 3-6

Table 3-3 POSSIBLE SOURCES OF EMISSIONS 3-16

Table 3-4 EMISSION SOURCES AT NON-METALLIC MINERAL FACILITIES . . 3-18

Table 3-5 PARTICULATE EMISSION FACTORS FOR STONE CRUSHING PROCESS. 3-19

Table 3-6 RELATIVE CRUSHING MECHANISMS UTILIZED BY VARIOUS CRUSHERS. 3-23

Table 3-7 APPROXIMATE CAPACITIES OF JAW CRUSHERS. 3-27

Table 3-8 APPROXIMATE CAPACITIES OF GYRATORY CRUSHERS 3-27

Table 3-9 PERFORMANCE DATA FOR CONE CRUSHERS. 3-29

Table 4-1 PARTICULATE EMISSION SOURCES FOR THE EXTRACTION AND PROCESSING OF NON-METALLIC MINERALS 4-2

Table 4-2 BAGHOUSE UNITS TESTED BY EPA. 4-34

Table 4-3 AIR-TO-CLOTH RATIOS FOR FABRIC FILTERS USED FOR EXHAUST EMISSION CONTROL. 4-38

Table 4-4 BAGHOUSE UNITS TESTED BY EPA (METALLIC MINERAL PROCESSING) 4-42

Table 4-5 OPACITY MEASUREMENTS FROM BAGHOUSE EXHUAST STACKS . . . 4-47

Table 4-6 SUMMARY OF VISIBLE EMISSIONS MEASUREMENTS FROM FUGITIVE SOURCES AT NON-METALLIC MINERAL PLANTS 4-49

Table 4-7 SUMMARY OF VISIBLE EMISSIONS MEASUREMENTS FROM FUGITIVE NONCRUSHING SOURCES CONTROLLED BY WET SUPPRESSION (ACCORDING TO EPA METHOD 9) 4-52

Table 6-1 MODEL PLANTS FOR ESTIMATING ENVIRONMENTAL AND ECONOMIC IMPACT 6-2

LIST OF TABLES (continued)

Page

Table 8-30 FABRIC FILTER COSTS FOR NEW MODEL PLANT 2: 135 Mg/Hour. 8-68

Table 8-31 FABRIC FILTER COSTS FOR NEW MODEL PLANT 2: 270 Mg/Hour. 8-69

Table 8-32 FABRIC FILTER COSTS FOR NEW MODEL PLANT 2: 540 Mg/Hour. 8-70

Table 8-33 FABRIC FILTER COSTS FOR EXPANDED MODEL PLANTS 8-75

Table 8-34 FABRIC FILTER COSTS FOR 32 Mg/Hour EXPANDED MODEL PLANT 8-76

Table 8-35 MONITORING COSTS FOR NON-METALLIC MINERALS MODEL PLANTS. 8-85

Table 8-36 RANK ORDER OF INDUSTRIES WITH HIGHEST CONTROL COST IMPACT. 8-101

Table 8-37 PLANT INVESTMENT COSTS. 8-104

Table 8-38 EXPANSION INVESTMENT COSTS. 8-105

Table 8-39 DISCOUNTED CASH FLOW ANALYSES CRUSHED STONE PLANT 136 Mg/Hour (150 tph) (IN THOUSANDS OF DOLLARS) 8-108

Table 8-40 SUMMARY OF DCF RESULTS. 8-113

Table 8-41 SUMMARY OF DCF RESULTS. 8-115

Table 8-42 ESTIMATED NUMBER OF TYPICAL NEW PLANT REQUIRED TO MEET PROJECT PRODUCTION 8-119

Table 8-43 ANNUALIZED CAPITAL AND OPERATING CONTROL COSTS FOR NEW PLANT CONSTRUCTION 8-120

Table 8-44 ANNUALIZED CONTROL COST PER TON OF INDUSTRY OUTPUT IN 5th YEAR AND CONTROL COST AS PERCENT OF SELLING PRICE 8-121

1. SUMMARY

1.1 REGULATORY ALTERNATIVES

Regulatory alternatives to limit emissions of particulate matter from new, modified, and reconstructed non-metallic mineral processing plants and the environmental and economic impacts of these alternatives are presented in this document. This source was listed August 21, 1979 (44 FR 49222) in accordance with section 111(b)(1)(A) of the Clean Air Act as contributing signficantly to air pollution, which may reasonably be anticipated to endanger public health or welfare. Appendix B contains a cross-reference between this document and the Agency's guidelines for Environmental Impact Statements.

Regulatory alternatives have been developed for processing of the following minerals:

- Crushed and broken stone
  - Limestone, Dolomite, Granite, Traprock, Sandstone, Quartz, Quartzite, Marl, Marble, Slate, Shell
- Sand and gravel
- Clay
  - Kaolin, Fireclay, Bentonite, Fuller's Earth, Ball Clay
- Rock salt
- Gypsum
- Sodium compounds
  - Chloride, Carbonate, Sulfate
- Pumice
- Gilsonite
- Boron
  - Borax, Kernite, Colemanite
- Barite
- Fluorspar
- Talc and Pyrophyllite
- Feldspar
- Diatomite
- Perlite
- Vermiculite
- Mica
- Kyanite
  - Andalusite, Sillimanite, Topaz, Dumortierite

The regulatory alternatives would limit emissions of particulate matter from the following process equipment at a plant: crushers, grinding mills (including air separators, classifiers, and conveyors), screens, bucket elevators, belt conveyors, bagging operations, storage bins, and enclosed truck and railcar loading stations. Unit operations not included are drilling, blasting, loading at the mine, hauling, drying, stockpiling, conveying (other than at transfer points), and windblown dust from stockpiles, roads, and plant yards.

Three regulatory alternatives were considered: (1) to set no standards; (2) to set standards based on baghouses; and (3) to set standards based on baghouses and wet dust suppression systems. A matrix summarizing the environmental and economic impacts associated with the three regulatory alternatives is included in Table 1.1. Alternatives 2 and 3 would limit both fugitive and stack emissions at the affected facilities. Fugitive emissions, which are emissions not collected by a capture system, would be limited to 10 percent opacity under alternative 2. Under alternative 3, fugitive emissions at all process operations except crushing would be subject to the limitation described above. At crushers, fugitive emissions would be limited to 15 percent opacity. Under both alternatives, stack emissions, which are emissions collected by a capture system, would be limited to a concentration of particulate matter of 0.05 gram per dry standard cubic meter (g/dscm) (0.02 grain per dry standard cubic foot (gr/dscf)) and 7 percent opacity.

1.2 ENVIRONMENTAL IMPACT

The beneficial and adverse environmental impact associated with regulatory alternatives 2 and 3 are presented in this section. These impacts are discussed in detail in Chapter 7, Environmental Impact.

TABLE 1.1 MATRIX OF ENVIRONMENTAL AND ECONOMIC IMPACTS OF REGULATORY ALTERNATIVES

Administrative action	Air impact	Water impact	Solid waste impact	Energy impact	Noise and radiation impact	Economic impact	Inflation impact
Regulatory Alternative 1	0	0	0	0	0	0	0
Regulatory Alternative 2	+4	0	-1	-2	0	-3	0
Regulatory Alternative 3	+4	0	-1	-1	0	-2	0

KEY: + Beneficial impact

- Adverse impact

0 No impact
1 Negligible impact
2 Small impact
3 Moderate impact
4 Large impact

About 550 new non-metallic mineral processing plants will be needed to process the projected increased production in the first 5 years after proposal. By the fifth year, regulatory alternatives 2 and 3 would reduce the total amount of particulate matter emissions to the atmosphere by 41,000 megagrams per year (45,000 tons per year). This reduction is 90 percent greater than that achievable with a typical State process weight regulation. This will result in a large positive environmental impact.

The utilization of dry collection techniques (particulate capture combined with a dry emission control device) for control generates no water effluent discharge. In cases where wet suppression techniques could be used, most of the water adheres to the material being processed, resulting in no significant water discharge. Consequently, the regulatory alternatives for the non-metallic mineral industry would have no water pollution impact.

There would be an insignificant negative solid waste disposal impact resulting from the use of dry emission control techniques. Approximately 1.4 megagrams (1.6 tons) of solid waste are collected for every 250 megagrams (278 tons) of material processed. In many cases, this material may be recycled back into the process, sold, or used for a variety of purposes. Where no market exists for the collected fines, they are typically disposed of in the mine or in an isolated location in the quarry. Where wet dust suppression can be used, no solid waste disposal problem exists over that resulting from normal operation.

The estimated incremental energy requirements of both regulatory alternatives result from comparing the use of fabric filters (baghouses) to control particulate matter emissions to the use of no control system. The estimates indicate a greater impact than would actually occur because it is expected that less-energy consuming wet dust suppression systems would be used in many cases. In addition, many new plants would use baghouses or a combination of baghouses and water sprays to meet existing State regulations.

The energy required to control all new non-metallic mineral processing plants constructed by 1985 to the levels of regulatory alternatives 2 and 3 would be about 0.21 million megawatt-hours (0.34 million kilowatt-hours) per year. This would be about a 15 percent increase over the amount of energy which would otherwise be required to meet project capacity additions without controls. This increase would have a minor impact on national energy demand.

When compared to the noise emanating from crushing and grinding process equipment, any additional noise from properly designed exhaust fans for the control system would be insignificant. Consequently, no significant noise impact is anticipated due to the implementation of either regulatory alternative 2 or 3 for non-metallic mineral plants. There are no known radiation impacts associated with the regulatory alternatives.

1.3 ECONOMIC IMPACT

The economic impacts associated with regulatory alternatives 2 and 3 are presented in this section. These impacts are discussed in detail in Chapter 8, Economic Impact.

The costs and economic impacts associated with regulatory alternatives 2 and 3 are considered reasonable. The estimated impacts are based on a comparison of fabric filter (baghouse) use to no control. Less expensive wet dust suppression systems may be used in some cases. Also, many new plants would use baghouses or a combination of baghouses and water sprays to meet existing State regulations. Thus, the actual economic impact of these regulatory alternatives would probably be considerably less than the estimates summarized below.

The costs associated with these regulatory alternatives would not prevent construction of new non-metallic processing plants which would be built in the absence of any new regulations. However, the incremental costs associated with the best system of emission reduction may preclude the construction of new pumice plants and common clay plants with capacities of 9.1 Mg/hr (10 tons/hr) or less; fixed sand and gravel plants and crushed stone plants with capacities of 22.7 Mg/hr (25 tons/hr) or less; and portable sand and gravel plants and crushed stone plants with capacities of 136.4 Mg/hr (150 tons/hr) or less.

The total additional capital cost for all new plants would be about $107 million for the first 5 years the proposed standards would be in effect. These costs would vary for each industry, ranging from about $93,000 for several minerals to $82.5 million for crushed stone. The total annualized costs in the fifth year would increase by about $28 million for crushed stone. The average annualized control cost per ton of output in the fifth year would range from $0.005 for sand and gravel to $0.137 for kyanite. For all minerals, the annualized control cost is less than 2 percent of the annual revenue for that industry.

2. INTRODUCTION

2.1 BACKGROUND AND AUTHORITY FOR STANDARDS

Before standards of performance are proposed as a Federal regulation, air pollution control methods available to the affected industry and the associated costs of installing and maintaining the control equipment are examined in detail. Various levels of control based on different technologies and degrees of efficiency are expressed as regulatory alternatives. Each of these alternatives is studied by EPA as a prospective basis for a standard. The alternatives are investigated in terms of their impacts on the economics and well-being of the industry, the impacts on the national economy, and the impacts on the environment. This document summarizes the information obtained through these studies so that interested persons will be able to see the information considered by EPA in the development of the proposed standard.

Standards of performance for new stationary sources are established under section 111 of the Clean Air Act (42 U.S.C. 7411) as amended, hereinafter referred to as the Act. Section 111 directs the Administrator to establish standards of performance for any category of new stationary source of air pollution which ". . . causes, or contributes significantly to air pollution which may reasonably be anticipated to endanger public health or welfare."

The Act requires that standards of performance for stationary sources reflect ". . . the degree of emission reduction achievable which (taking into consideration the cost of achieving such emission reduction, and any nonair quality health and environmental impact and energy requirements) the Administrator determines has been adequately demonstrated for that category of sources." The standards apply only to stationary sources, the construction or modification of which commences after regulations are proposed by publication in the Federal Register.

The 1977 amendments to the Act altered or added numerous provisions that apply to the process of establishing standards of performance.

1. EPA is required to review the standards of performance every 4 years and, if appropriate, revise them.

2. EPA is authorized to promulgate a standard based on design, equipment, work practice, or operational procedures when a standard based on emission levels is not feasible.

3. The term "standards of performance" is redefined, and a new term "technological system of continuous emission reduction" is defined. The new definitions clarify that the control system must be continuous and may include a low- or non-polluting process or operation.

4. The time between the proposal and promulgation of a standard under section 111 of the Act may be extended to 6 months.

Standards of performance, by themselves, do not guarantee protection of health or welfare because they are not designed to achieve any specific air quality levels. Rather, they are designed to reflect the degree of emission limitation achievable through application of the best adequately demonstrated technological system of continuous emission reduction, taking into consideration the cost of achieving such emission reduction, any non-air-quality health and environmental impacts, and energy requirements.

Congress had several reasons for including these requirements. First, standards with a degree of uniformity are needed to avoid situations where some States may attract industries by relaxing standards relative to other States. Second, stringent standards enhance the potential for long-term growth. Third, stringent standards may help achieve long-term cost savings by avoiding the need for more expensive retrofitting when pollution ceilings may be reduced in the future. Fourth, certain types of standards for coalburning sources can adversely affect the coal market by driving up the price of low-sulfur coal or effectively excluding certain coals from the reserve base because their untreated pollution potentials are high. Congress does not intend that new source performance standards contribute to these problems. Fifth, the standard-setting process should create incentives for improved technology.

Promulgation of standards of performance does not prevent State or local agencies from adopting more stringent emission limitations for the same sources. States are free under section 116 of the Act to establish even more stringent emission limits than those established under section 111 or those necessary to attain or maintain the National Ambient Air Quality Standards (NAAQS) under section 110. Thus, new sources may in some cases be subject to limitations more stringent than standards of performance under section 111, and prospective owners and operators of new sources should be aware of this possibility in planning for such facilities.

A similar situation may arise when a major emitting facility is to be constructed in a geographic area that falls under the prevention of significant deterioration of air quality provisions of Part C of the Act. These provisions require, among other things, that major emitting facilities to be constructed in such areas are to be subject to best available control technology. The term Best Available Control Technology (BACT), as defined in the Act, means

> . . . an emission limitation based on the maximum degree of reduction of each pollutant subject to regulation under this Act emitted from, or which results from, any major emitting facility, which the permitting authority, on a case-by-case basis, taking into account energy, environmental, and economic impacts and other costs, determines is achievable for such facility through application of production processes and available methods, systems, and techniques, including fuel cleaning or treatment or innovative fuel combustion techniques for control of each such pollutant. In no event shall application of "best available control technology" result in emissions of any pollutants which will exceed the emissions allowed by any applicable standard established pursuant to sections 111 or 112 of this Act. (Section 169(3))

Although standards of performance are normally structured in terms of numerical emission limits where feasible, alternative approaches are sometimes necessary. In some cases physical measurement of emissions from a new source may be impractical or exorbitantly expensive. Section 111(h) provides that the Administrator may promulgate a design or equipment standard in those cases where it is not feasible to prescribe or enforce a standard of performance. For example, emissions of hydrocarbons from storage vessels for petroleum liquids are greatest during tank filling. The nature of the emissions, high concentrations for short periods during filling and low concentrations for longer periods during storage, and the configuration of storage tanks make direct emission measurement impractical. Therefore, a more practical approach to standards of performance for storage vessels has been equipment specification.

In addition, section 111(i) authorizes the Administrator to grant waivers of compliance to permit a source to use innovative continuous emission control technology. In order to grant the waiver, the Administrator must find: (1) a substantial likelihood that the technology will produce greater emission reductions than the standards require or an equivalent reduction at lower economic energy or environmental cost; (2) the proposed system has not been adequately demonstrated; (3) the technology will not cause or contribute to an unreasonable risk to the public health, welfare, or safety; (4) the governor of the State where the source is located consents; and (5) the waiver will not prevent the attainment or maintenance of any ambient standard. A waiver may have conditions attached to assure the source will not prevent attainment of any NAAQS. Any such condition will have the force of a performance standard. Finally, waivers have definite end dates and may be terminated earlier if the conditions are not met or if the system fails to perform as expected. In such a case, the source may be given up to 3 years to meet the standards with a mandatory progress schedule.

2.2 SELECTION OF CATEGORIES OF STATIONARY SOURCES

Section 111 of the Act directs the Adminstrator to list categories of stationary sources. The Administrator ". . . shall include a category of sources in such list if in his judgment it causes, or contributes significantly to, air pollution which may reasonably be anticipated to endanger public health or welfare." Proposal and promulgation of standards of performance are to follow.

Since passage of the Clean Air Amendments of 1970, considerable attention has been given to the development of a system for assigning priorities to various source categories. The approach specifies areas of interest by considering the broad strategy of the Agency for implementing the Clean Air Act. Often, these "areas" are actually pollutants emitted by stationary sources. Source categories that emit these pollutants are evaluated and ranked by a process involving such factors as (1) the level of emission control (if any) already required by State regulations, (2) estimated levels of control that might be required from standards of performance for the source category, (3) projections of growth and replacement of existing facilities for the source category, and (4) the estimated incremental amount of air pollution that could be prevented in a preselected future year by standards of performance for the source category. Sources for which new source performance standards were promulgated or under development during 1977, or earlier, were selected on these criteria.

The Act amendments of August 1977 establish specific criteria to be used in determining priorities for all major source categories not yet listed by EPA. These are (1) the quantity of air pollutant emissions that each such category will emit, or will be designed to emit; (2) the extent to which each such pollutant may reasonably be anticipated to endanger public health or welfare; and (3) the mobility and competitive nature of each such category of sources and the consequent need for nationally applicable new source standards of performance.

The Administrator is to promulgate standards for these categories according to the schedule referred to earlier.

In some cases it may not be feasible immediately to develop a standard for a source category with a high priority. This might happen when a program of research is needed to develop control techniques or because techniques for sampling and measuring emissions may require refinement. In the developing of standards, differences in the time required to complete the necessary investigation for different source categories must also be considered. For example, substantially more time may be necessary if numerous pollutants must be investigated from a single source category. Further, even late in the development process the schedule for completion of a standard may change. For example, inablility to obtain emission data from well-controlled sources in time to pursue the development process in a systematic fashion may force a change in scheduling. Nevertheless, priority ranking is, and will continue to be, used to establish the order in which projects are initiated and resources assigned.

After the source category has been chosen, the types of facilities within the source category to which the standard will apply must be determined. A source category may have several facilities that cause air pollution, and emissions from some of these facilities may vary from insignificant to very expensive to control. Economic studies of the source category and of applicable control technology may show that air pollution control is better served by applying standards to the more severe pollution sources. For this reason, and because there is no adequately demonstrated system for controlling emissions from certain facilities, standards often do not apply to all facilities at a source. For the same reasons, the standards may not apply to all air pollutants emitted. Thus, although a source category may be selected to be covered by a standard of performance, not all pollutants or facilities within that source category may be covered by the standards.

2.3 PROCEDURE FOR DEVELOPMENT OF STANDARDS OF PERFORMANCE

Standards of performance must (1) realistically reflect best demonstrated control practice; (2) adequately consider the cost, the non-air-quality health and environmental impacts, and the energy requirements of such control; (3) be applicable to existing sources that are modified or reconstructed as well as new installations; and (4) meet these conditions for all variations of operating conditions being considered anywhere in the country.

The objective of a program for developing standards is to identify the best technological system of continuous emission reduction that has been adequately demonstrated. The standard-setting process involves three principal phases of activity: (1) information gathering, (2) analysis of the information, and (3) development of the standard of performance.

During the information-gathering phase, industries are queried through a telephone survey, letters of inquiry, and plant visits by EPA representatives. Information is also gathered from many other sources, and a literature search is conducted. From the knowledge acquired about the industry, EPA selects certain plants at which emission tests are conducted to provide reliable data that characterize the pollutant emissions from well-controlled existing facilities.

In the second phase of a project, the information about the industry and the pollutants emitted is used in analytical studies. Hypothetical "model plants" are defined to provide a common basis for analysis. The model plant definitions, national pollutant emission data, and existing State regulations governing emissions from the source category are then used in establishing "regulatory alternatives." These regulatory alternatives are essentially different levels of emission control.

EPA conducts studies to determine the impact of each regulatory alternative on the economics of the industry and on the national economy, on the environment, and on energy consumption. From several possibly applicable alternatives, EPA selects the single most plausible regulatory alternative as the basis for a standard of performance for the source category under study.

In the third phase of a project, the selected regulatory alternative is translated into a standard of performance, which, in turn, is written in the form of a Federal regulation. The Federal regulation, when applied to newly constructed plants, will limit emissions to the levels indicated in the selected regulatory alternative.

As early as is practical in each standard-setting project, EPA representatives discuss the possibilities of a standard and the form it might take with members of the National Air Pollution Control Techniques Advisory Committee. Industry representatives and other interested parties also participate in these meetings.

The information acquired in the project is summarized in the Background Information Document (BID). The BID, the standard, and a preamble explaining the standard are widely circulated to the industry being considered for control, environmental groups, other government agencies, and offices within EPA. Through this extensive review process, the points of view of expert reviewers are taken into consideration as changes are made to the documentation.

A "proposal package" is assembled and sent through the offices of EPA Assistant Administrators for concurrence before the proposed standard is officially endorsed by the EPA Administrator. After being approved by the EPA Administrator, the preamble and the proposed regulation are published in the Federal Register.

As a part of the Federal Register announcement of the proposed regulation, the public is invited to participate in the standard-setting process. EPA invites written comments on the proposal and also holds a public hearing to discuss the proposed standard with interested parties. All public comments are summarized and incorporated into a second volume of the BID. All information reviewed and generated in studies in support of the standard of performance is available to the public in a "docket" on file in Washington, D. C.

Comments from the public are evaluated, and the standard of performance may be altered in response to the comments.

The significant comments and EPA's position on the issues raised are included in the "preamble" of a promulgation package," which also contains the draft of the final regulation. The regulation is then subjected to another round of review and refinement until it is approved by the EPA Administrator. After the Administrator signs the regulation, it is published as a "final rule" in the Federal Register.

2.4 CONSIDERATION OF COSTS

Section 317 of the Act requires an economic impact assessment with respect to any standard of performance established under Section 111 of the Act. The assessment is required to contain an analysis of: (1) the costs of compliance with the regulation, including the extent to which the cost of compliance varies depending on the effective date of the regulation and the development of less expensive or more efficient methods of compliance; (2) the potential inflationary or recessionary effects of the regulation; (3) the effects the regulation might have on small business with respect to competition; (4) the effects of the regulation on consumer costs; and (5) the effects of the regulation on energy use. Section 317 also requires that the economic impact assessment be as extensive as practicable.

The economic impact of a proposed standard upon an industry is usually addressed both in absolute terms and in terms of the control costs that would be incurred as a result of compliance with typical, existing State control regulations. An incremental approach is necessary because both new and existing plants would be required to comply with State regulations in the absence of a Federal standard of performance. This approach requires a detailed analysis of the economic impact from the cost differential that would exist between a proposed standard of performance and the typical State standard.

Air pollutant emissions may cause water pollution problems, and captured potential air pollutants may pose a solid waste disposal problem. The total environmental impact of an emission source must, therefore, be analyzed and the costs determined whenever possible.

A thorough study of the profitability and price-setting mechanisms of the industry is essential to the analysis so that an accurate estimate of potential adverse economic impacts can be made for proposed standards. It is also essential to know the capital requirements for pollution control systems already placed on plants so that the additional capital requirements necessitated by these Federal standards can be placed in proper perspective. Finally, it is necessary to assess the availability of capital to provide the additional control equipment needed to meet the standards of performance.

2.5 CONSIDERATION OF ENVIRONMENTAL IMPACTS

Section 102(2)(C) of the National Environmental Policy Act (NEPA) of 1969 requires Federal agencies to prepare detailed environmental impact statements on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment. The objective of NEPA is to build into the decisionmaking process of Federal agencies a careful consideration of all environmental aspects of proposed actions.

In a number of legal challenges to standards of performance for various industries, the United States Court of Appeals for the District of Columbia Circuit has held that environmental impact statements need not be prepared by the Agency for proposed actions under section 111 of the Clean Air Act. Essentially, the Court of Appeals has determined that the best system of emission reduction requires the Administrator to take into account counterproductive environmental effects of a proposed standard, as well as economic costs to the industry. On this basis, therefore, the Court established a narrow exemption from NEPA for EPA determination under section 111.

In addition to these judicial determinations, the Energy Supply and Environmental Coordination Act (ESECA) of 1974 (PL-93-319) specifically exempted proposed actions under the Clean Air Act from NEPA requirements. According to section 7(c)(1), "No action taken under the Clean Air Act shall be deemed a major Federal action significantly affecting the quality of the human environment within the meaning of the National Environmental Policy Act of 1969." (15 U.S.C. 793(c)(1))

Nevertheless, the Agency has concluded that the preparation of environmental impact statements could have beneficial effects on certain regulatory actions. Consequently, although not legally required to do so by section 102(2)(C) of NEPA, EPA has adopted a policy requiring that environmental impact statements be prepared for various regulatory actions, including standards of performance developed under section 111 of the Act. This voluntary preparation of environmental impact statements, however, in no way legally subjects the Agency to NEPA requirements.

To implement this policy, a separate section in this document is devoted solely to an analysis of the potential environmental impacts associated with the proposed standards. Both adverse and beneficial impacts in such areas as air and water pollution, increased solid waste disposal, and increased energy consumption are discussed.

2.6 IMPACT ON EXISTING SOURCES

Section 111 of the Act defines a new source as ". . . any stationary source, the construction or modification of which is commenced . . ." after the proposed standards are published. An existing source is redefined as a new source if "modified" or "reconstructed" as defined in amendments to the general provisions of Subpart A of 40 CFR Part 60, which were promulgated in the Federal Register on December 16, 1975 (40 FR 58416).

Promulgation of a standard of performance requires States to establish standards of performance for existing sources in the same industry under section 111 (d) of the Act if the standard for new sources limits emissions of a designated pollutant (i.e., a pollutant for which air quality criteria have not been issued under section 108 or which has not been listed as a hazardous pollutant under section 112). If a State does not act, EPA must establish such standards. General provisions outlining procedures for control of existing sources under section 111(d) were promulgated on November 17, 1975, as Subpart B of 40 CFR Part 60 (40 FR 53340).

2.7 REVISION OF STANDARDS OF PERFORMANCE

Congress was aware that the level of air pollution control achievable by any industry may improve with technological advances. Accordingly, section 111 of the Act provides that the Administrator ". . . shall, at least every 4 years, review and, if appropriate, revise . . ." the standards. Revisions are made to assure that the standards continue to reflect the best systems that become available in the future. Such revisions will not be retroactive, but will apply to stationary sources constructed or modified after the proposal of the revised standards.

3. THE NON-METALLIC MINERALS INDUSTRY

3.1 GENERAL

There are many non-metallic minerals which are individually produced in a wide range of quantities. For example, the annual domestic demand for sand, gravel and stone is quoted in millions of tons, whereas the production of industrial diamonds and gem stones is measured in carats. Previous EPA studies have investigated some of these non-metallic minerals, namely, coal, phosphate rock and asbestos. The 18 non-metallic minerals selected for investigation in this study are:

Crushed and Broken Stone
Sand and Gravel
Clay
Rock Salt
Gypsum
Sodium compounds
Pumice
Gilsonite
Talc
Boron
Barite
Fluorspar
Feldspar
Diatomite
Perlite
Vermiculite
Mica
Kyanite

These 18 categories are based upon Bureau of Mines classifications and are the highest mined production segments of the non-metallic minerals industry which have crushing and grinding operations, excluding coal, phosphate rock, and asbestos.

Total domestic production of these non-metallic minerals for 1975 was about 1605 million megagrams (1769 million short tons). The estimated domestic production level of these minerals in 1980 has been projected to be 1829 million megagrams (2017 million short tons). Value of the minerals ranges from 1.1 dollars/megagram (1.0 dollars/ton) for low grade clay, to 276 dollars/megagram (250 dollars/ton) for high grade talc. Geographically, the non-metallic minerals industry is highly dispersed, with all States reporting production of at least one of these 18 non-metallic minerals. The industry is also extremely diverse in terms of production capacities per facility (from 5 to several thousand tons per hour) and end product uses.

3.1.1 Industry Characteristics

Table 3.1 presents industry characteristics for each mineral under consideration. Crushed stone and sand and gravel are by far the largest segments, accounting for 1523 million megagrams (1680 million tons) of the 1605 million megagrams (1769 million tons) produced by the 18 industries. There are about 5500 processing plants in the sand and gravel industry and about 4800 quarries worked in the crushed stone industry. Each of the other industries has less than 100 processing plants, except for the clay industry which has about 120 plants.

Sand and gravel plants are located in every state. Crushed stone plants are located in every state except Delaware. Clay plants are located in every state except Vermont, Rhode Island, and Alaska. Processing plants for the other industries are usually distributed among a few states where those minerals deposits are located. One of the minerals is principally mined and processed in only one state: boron only in California.

Projected growth rates are also presented in Table 3.1. The growth rates are projected to increase at compounded annual rates of up to 6 percent through the year 1985.

TABLE 3-1 INDUSTRY CHARACTERISTICS[1-3]

Mineral	1975 Production 1000 megagrams (1000 tons)	1975 Price (Dollars/Mg)	Annual growth rate (%)	Major producing states in order of production	Number of active operations
Crushed and broken stone	807,000 (890,000)	2.63	4.0	Pennsylvania Illinois Texas Florida Ohio	4800 (quarries)
Sand and gravel	716,015 (789,432)	1.97	1.0	Alaska California Michigan Illinois Texas Ohio	5500 (plants)
Clay	44,485 (49,047)	1.10-221.00	3.3	Georgia Texas Ohio North Carolina	120
Rock Salt	14,928 (13,540)	29.78	2.0	Texas New York Louisiana	21
Gypsum (crude)	8,844 (9,751)	5.05	2.0	California Michigan Iowa Texas	69 (mines)
Sodium compounds[*]	4,529 (4,895)	46.54-45.75[†]	2.5	California Texas	37
Pumice	3,530 (3,892)	3.17	3.5	Oregon California Arizona New Mexico	235
Gilsonite	90 (100)	-	2.0	Utah	1
Talc	875 (965)	5.50-276.00	4.0	Vermont Texas California	52
Boron	1,063 (1,172)	110	5.0	California	6
Barite	1,167 (1,287)	17.71	2.2	Nevada Missouri	31
Fluorspar	126 (140)	88-106	3.0	Illinois	15

(continued)

TABLE 3.1 (continued)

Mineral	1975 Production 1000 megagrams (1000 tons)	1975 Price (Dollars/Mg)	Annual growth rate (%)	Major producing states in order of production	Number of active operations
Feldspar	607 (670)	19.30	4.0	North Carolina	15
Diatomite	519 (573)	88.25	5.5	California Kansas Nevada	16
Perlite	640 (706)	15.72	4.0	New Mexico	13
Vermiculite	299 (330)	46.06	4.0	Montana South Carolina	2
Mica	122 (135)	42.64	4.0	North Carolina New Mexico	17
Kyanite	85 (94)**	-	6.0	Virginia Georgia	3

*Natural soda ash.

^Sodium sulfate price.

*Estimates for 1974.

3.1.2 End Uses

End uses for the non-metallic minerals are many and diverse. The minerals may be used either directly in their natural state or processed into a variety of manufactured products. Generally, they can be classified as either minerals for the construction industry; minerals for the chemical and fertilizer industries; or clay, ceramic, refractory and miscellaneous minerals. Minerals generally used for construction are crushed and broken stone, sand and gravel, gypsum, gilsonite, perlite, pumice, vermiculite, and mica. Minerals generally used in the chemical and fertilizer industries are barite, fluorspar, boron, rock salt, and sodium compounds. Clay, feldspar, kyanite, talc and diatomite can be generally classified as clay, ceramic, refractory, and miscellaneous minerals. Table 3.2 lists the major uses of each individual mineral.

3.1.3 Rock Types and Distribution

Major rock types processed by the crushed and broken stone industry include limestone and dolomite (which accounted for 73.2 percent of the total tonnage in 1973 and has the widest and most important end use range); granite (11.4 percent), trap rock (7.9 percent) and sandstone, quartz and quartzite (2.9 percent). Rock types including calcereous marl, marble, shell, slate and miscellaneous others accounted for only 4.6 percent. Classifications used by the industry vary considerably and in many cases do not reflect actual geological definitions.

Limestone and dolomite are sedimentary rocks formed from accumulations of animal remains or chemical precipitation of carbonates in water. In a pure state, limestone consists of crystalline or granular calcium carbonate (calcite), while dolomite consists of calcium-magnesium carbonate (dolomite).

TABLE 3.2 MAJOR USES OF THE NON-METALLIC MINERALS

Mineral	Major uses
Crushed and broken stone	Construction, lime manufacturing
Sand and gravel	Construction
Clay	Bricks, cement, refractory, paper
Rock salt	Highway use, chlorine
Gypsum	Wallboard, plaster, cement, agriculture
Sodium compounds	Glass, chemicals, paper
Pumice	Road construction, concrete
Gilsonite	Asphalt paving
Talc	Ceramics, paint, toilet preparations
Boron	Glass, soaps, fertilizer
Barite	Drilling mud, chemicals
Fluorspar	Hydrofluoric acid, iron and steel, glass
Feldspar	Glass, ceramics
Diatomite	Filtration, filters
Perlite	Insulation, filter aid, plaster aggregate
Vermiculite	Concrete
Mica	Paint, joint cement, roofing
Kyanite	Refractories, ceramics

Both are often found together in the same rock deposit. Depending on the proportions of each, the rock may be classified as limestone, dolomitic limestone, calcareous dolomite or dolomite. Deposits are common and are distributed throughout most parts of the country, although primarily located in the Central, Middle Atlantic and South Atlantic regions which combined accounted for over 93 percent of the total production in 1973.

Commercially, granite consists of any light-colored, coarse-grained igneous rock. It is composed chiefly of quartz, feldspar and, usually mica. Deposits are located in the South Atlantic, northeastern, North Central and western regions of the country. The South Atlantic region accounted for more than 77 percent of the total tonnage of granite produced in 1973.

Trap rock includes any dark colored, fine-grained igneous rock composed of the ferro-magnesian minerals and basic feldspars with little or no quartz. Common varieties include basalts, diabases and gabbros. Deposits are mostly found in the New England, Middle Atlantic and Pacific regions, which combined accounted for 76 percent of all trap rock produced in 1973.

Sandstones and quartzitic rocks are scattered throughout the country. Sandstones are sedimentary rocks composed predominantly of cemented quartz grains. The cementing material may be calcium carbonate, iron oxide or clay. Quartzites are metamorphosed siliceous sandstones. All regions accounted for some production of sandstone and quartz, with the Pacific and West South Central and Middle Atlantic States combining for 60 percent of the total.

Sand and gravel are products of the weathering of rocks and thus consist predominantly of silica. Often, varying amounts of other minerals such as iron oxides, mica, and feldspar are present. Deposits are common and are distributed throughout the country.

Clays are a group of fine-grained non-metallic minerals which are mostly hydrous aluminum silicates that contain various amounts of organic and inorganic impurities. Clays are classified into six groups by the Bureau of Mines: kaolin, ball clay, fire clay, bentonite, fuller's earth, and miscellaneous (common) clay.

Kaolin is a clay in which the predominant clay mineral is kaolinite. Large quantities of high quality kaolin are found in Georgia. Ball clay consists principally of kaolinite, but has a higher silica-to-alumina ratio than is found in most kaolin, as well as larger quantities of mineral impurities and much organic material. Ball clays are mined in Kentucky, Tennessee, and New Jersey.

The terms "fire clay" and "stoneware clay" are based on refractoriness or on intended usage (fire clay indicating potential use for refractories, and stoneware clay indicating uses for such items as crocks, jugs, and jars). Fire clays are basically kaolinitic but include other clay minerals and impurities. Included under the general term fire clay are the diaspore, burley, and burley-flint clays. Fire clay deposits are widespread in the United States, with the greatest reserves being found in the Middle Atlantic region.

Bentonites are composed essentially of minerals of the montmorillonite group. The swelling type has a high sodium iron concentration, whereas the nonswelling types are usually high in calcium. Bentonite is presently produced in Wyoming and Montana.

Fuller's earths are essentially montmorillonite or attapulgite. A small area in Georgia and Florida contains the known reserve of attapulgite-type fuller's earth.

The term "miscellaneous (common) clay" is a statistical designation used by the Bureau of Mines to refer to clays and shales not included under the other five clay types. Miscellaneous clay may contain some kaolinite and montmorillonite, but illite usually predominates, particularly in the shales. Miscellaneous clay is widespread throughout the United States.

Rock salt consists of sodium chloride and is the chief source of all forms of sodium. Rock salt is mined on a large scale in Michigan, Texas, New York, Louisiana, Ohio, Utah, New Mexico, and Kansas.

Gypsum is a hydrous calcium sulfate normally formed as a chemical precipitate from marine waters of high salinity. Domestic reserves of gypsum are geographically distributed in 23 states. Areas deficient in gypsum reserves are Minnesota, Wisconsin, the Pacific Northwest, the New England States, the deep South to the east of Louisiana, and northern California.

Sodium is a chemically reactive metallic element used chiefly in the form of its many compounds. Although too reactive to be found in the uncombined form in nature, the compounds of sodium are plentiful. Sodium chloride (salt) is the chief source of all forms of sodium. Increasing quantities of sodium carbonate (soda ash) and sodium sulfate (salt cake) are produced from natural deposits of these compounds, but salt is still the main source of both. Natural sodium carbonate occurs in Wyoming and saline lake brines in California. Natural sodium sulfate is produced from deposits in California, Texas, and Wyoming.

Pumice is a rock of igneous origin, ranging from acidic to basic in composition, with a cellular structure formed by explosive or effusive volcanism. The commercial designation includes the more precise petrographic descriptions for pumice, pumicite (volcanic ash), volcanic cinders, and scoria. Deposits are mostly found in the Western States.

The mineral gilsonite is a variety of native asphalt which has many applications. Gilsonite occurs in large boulders, several inches across. It is a black, lustrous mineral found in the Uintah basin in Utah and Colorado.

The mineral talc is a soft hydrous magnesium silicate, $3\ MgO \cdot 4SiO_2 \cdot H_2O$. The talc of highest purity is derived from magnesium-rich metamorphic carbonate rocks; less pure talc from metamorphosed ultra basic igneous rocks. Soapstone is a term used for a massive form of rock containing the mineral. Pyrophyllite ($Al_2O_3 \cdot 4SiO_2 \cdot H_2O$) is a hydrous aluminum silicate similar to talc in properties. It is principally found in North Carolina. Talc-group minerals are principally produced in New York, Texas, Vermont, California, and Montana.

Boron is a versatile and useful element used mainly in the form of its many compounds, of which borax and boric acid are the best known. Many minerals contain boron, but only a few are commercially valuable as sources of boron. The principal boron minerals are borax, kernite, and colemanite. Half of the commercial world reserves are in southern California as bedded deposits of borax (sodium borate) and colemanite (calcium borate), or as solutions of boron minerals in Searles Lake brines.

Barite is almost pure barium sulfate ($BaSO_4$) and is the principal commercial mineral source of barium and barium compounds. The reserves are principally in Missouri and the southern Appalachian States, the remainder is in Arkansas, Nevada, and California.

Fluorine is derived from the mineral fluorite (CaF_2), commonly known as fluorspar. Fluorspar is principally found in deposits located in Kentucky and Illinois.

Feldspar is a general term used to designate a group of closely related minerals, especially abundant in igneous rocks and consisting essentially of aluminum silicates in combination with varying proportions of potassium, sodium, and calcium. The principal feldspar species are orthclase or microcline (both $K_2O \cdot Al_2O_3 \cdot 6SiO_2$), albite ($Na_2O \cdot Al_2O_3 \cdot 6SiO_2$) and anorthite ($CaO \cdot Al_2O_3 \cdot 2SiO_2$). North Carolina is the foremost domestic producer, followed in order of output by California, Connecticut, and Georgia.

Diatomite is a material of sedimentary origin consisting mainly of an accumulation of skeletons or frustules formed as a protective covering by diatoms, single-celled microscopic plants. The skeletons are essentially amorphous hydrated or opaline silica but occasionally are partly composed of alumina. The terms "diatomaceous earth" and "kieselguhr" are sometimes used interchangeably and are synonymous with diatomite. Diatomite is found only in the Western States with a substantial part of the total reserve found in the Lompoc, California area.

Perlite is chemically a metastable amorphous aluminum silicate with minor impurities and inclusions of various other metal oxides and minerals. Perlite is mostly found in the Western States.

Vermiculite is a micaceous mineral with a ferromagnesium-aluminum silicate composition and the property of exfoliating to a low-density material when heated. Presently, vermiculite is mined from deposits located in Montana and South Carolina.

Mica is a group name for a number of complex hydrous potassium aluminum silicate minerals differing in chemical composition and physical properties but characterized by excellent basal cleavage that facilitates splitting into thin, tough, flexible, elastic sheets. These minerals can be classified into four principal types named after the most common mineral in each group - muscovite (potassium mica), phlogopite (magnesium mica), biotite (iron mica), and lepidolite (lithium mica). The major producing regions in the United States are the Southeast and West.

Kyanite and the related minerals - andalusite, sillimanite, dumortierite, and topaz - are natural aluminum silicates which can be converted to mullite, a stable refractory raw material. Reserves of kyanite and the related minerals are mostly found in Virginia, North and South Carolina, Idaho, and Georgia.

3.2 NON-METALLIC MINERALS PREPARATION PROCESSES AND THEIR EMISSIONS

3.2.1 General Process Description

Non-metallic mineral processing involves extracting from the ground; loading, unloading, and dumping, conveying, crushing, screening, milling, and classifying. Some minerals processing also includes washing, drying, calcining, or flotation operations. The operations performed depend on the rock type and the desired product.

The mining techniques used for the extraction of non-metallic minerals vary with the particular mineral, the nature of the deposit, and the location of the deposit. Mining is carried out both underground and in open pits. Some minerals require blasting while others can be removed by bulldozer or dredging operations alone.

The non-metallic minerals are normally delivered to the processing plant by truck, and dumped into a hoppered feeder, usually a vibrating grizzly type, or on to screens, as illustrated in Figure 3.1. These screens separate or scalp the larger boulders from the finer rocks that do not require primary crushing, thus minimizing the load to the primary crusher. Jaw or gyratory

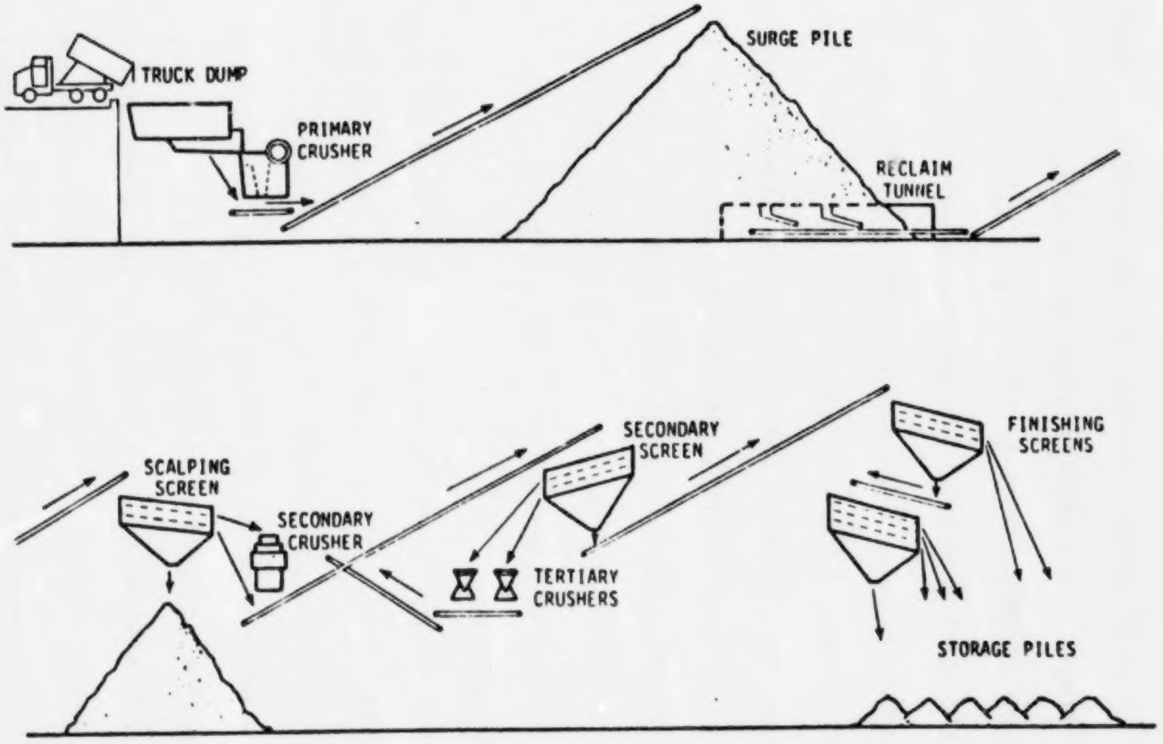

TRUCK DUMP
PRIMARY CRUSHER
SURGE PILE
RECLAIM TUNNEL
SCALPING SCREEN
SECONDARY CRUSHER
SECONDARY SCREEN
TERTIARY CRUSHERS
FINISHING SCREENS
STORAGE PILES

Figure 3.1 Flowsheet of a Typical Crushing Plant

crushers are usually used for initial reduction, although impact crushers are gaining favor for crushing low-abrasion rock, such as limestones, and talc, and where high reduction ratios are desired. The crusher product, normally 7.5 to 30 centimeters (3 to 12 inches) in size, and the grizzly throughs (undersize material) are discharged onto a belt conveyor and normally transported to either secondary screens and crusher, or to a surge pile or silo for temporary storage.

The secondary screens generally separate the process flow into either two or three fractions (oversize, undersize, and throughs) prior to the secondary crusher. The oversize is discharged to the secondary crusher for further reduction. The undersize, which require no further reduction at this stage, normally by-pass the secondary crusher. A third fraction, the throughs, is separated when processing some minerals. Throughs contain unwanted fines that are usually removed from the process flow and stockpiled as crusher-run material. For secondary crushing, gyratory or cone crushers are most commonly used, although impact crushers are used at some installations.

The product from the secondary crushing stage, usually 2.5 centimeters (one inch) or less in size, is normally transported to a secondary screen for further sizing. Sized material from this screen is either discharged directly to a tertiary crushing stage or conveyed to a fine-ore bin which supplies the milling stage. Cone crushers or hammermills are normally used for tertiary crushing. Rod mills, ball mills, and hammermills are normally used in the milling stage. The product from the tertiary crusher or the mill is usually conveyed to a type of classifier such as a dry vibrating screen system, an air separator, or a wet rake or spiral system (if wet grinding was employed) which also dewaters the material. The oversize is returned to the tertiary crusher or mill for further size reduction. At this point, some mineral end products of the desired grade are conveyed directly to finished product bins, or are stockpiled in open areas by conveyors or trucks. Other minerals such as talc or barite may require air classification to obtain the required mesh size, and treatment by flotation to obtain the necessary chemical purity and color.

Most non-metallic minerals require additional processing depending on the rock type and consumer requirements. In certain cases, especially in the crushed stone and sand and gravel industry, stone washing may be required to meet particular end product specifications or demands such as for concrete aggregate. Some minerals, especially certain lightweight aggregates, are washed and dried, sintered, or treated prior to primary crushing. Others are dried following secondary crushing or milling. Sand and gravel, crushed and broken stone, and most lightweight aggregates normally are not milled and are screened and shipped to the consumer after secondary or tertiary crushing. Table 3.3 lists the various unit process operations for each industry under consideration. Figures 3.1 and 3.2 show simplified diagrams of the typical process steps required for the non-metallic minerals investigated in this report.

3.2.2 Process Unit Operations and Their Emissions

Essentially all mining and mineral processing operations are potential sources of particulate emissions. Emissions may be categorized as either fugitive emissions or fugitive dust. Operations included within each category are listed in Table 3.4. Fugitive emission sources include those sources for which emissions are amenable to capture and subsequent control. Fugitive dust sources are not amenable to control using conventional control systems and generally involve the reentrainment of settled dust by wind or machine movement.

Information available on emissions from uncontrolled non-metallic minerals processing operations is limited. Estimates developed by EPA for uncontrolled

Table 3.3

Possible Sources of Emissions

Type of Plant	Crushers	Screens	Transfer Points	Grinders	Loading Operation	Bagging Operation	Dryers or Calciners	Drilling Operation
Crushed & Broken Stone	X	X	X		X			X
Sand & Gravel	X	X	X		X			
Clay	X	X	X	X	X	X	X	
Gypsum	X	X	X	X		X	X	
Pumice	X	X	X	X		X	X	
Feldspar	X	X	X	X	X		X	
Boron	X	X	X	X	X	X	X	X
Talc	X	X	X	X	X	X	X	X
Barite	X	X	X	X		X		
Diatomite	X	X	X	X		X	X	
Lightweight Aggregate	X	X	X	X	X	X	X	
Rock Salt	X	X	X					
Fluorspar	X	X	X	X			X	
Gilsonite	X	X					X	
Sodium Compounds	X	X		X				
Mica	X	X		X				
Kyanite	X			X			X	X

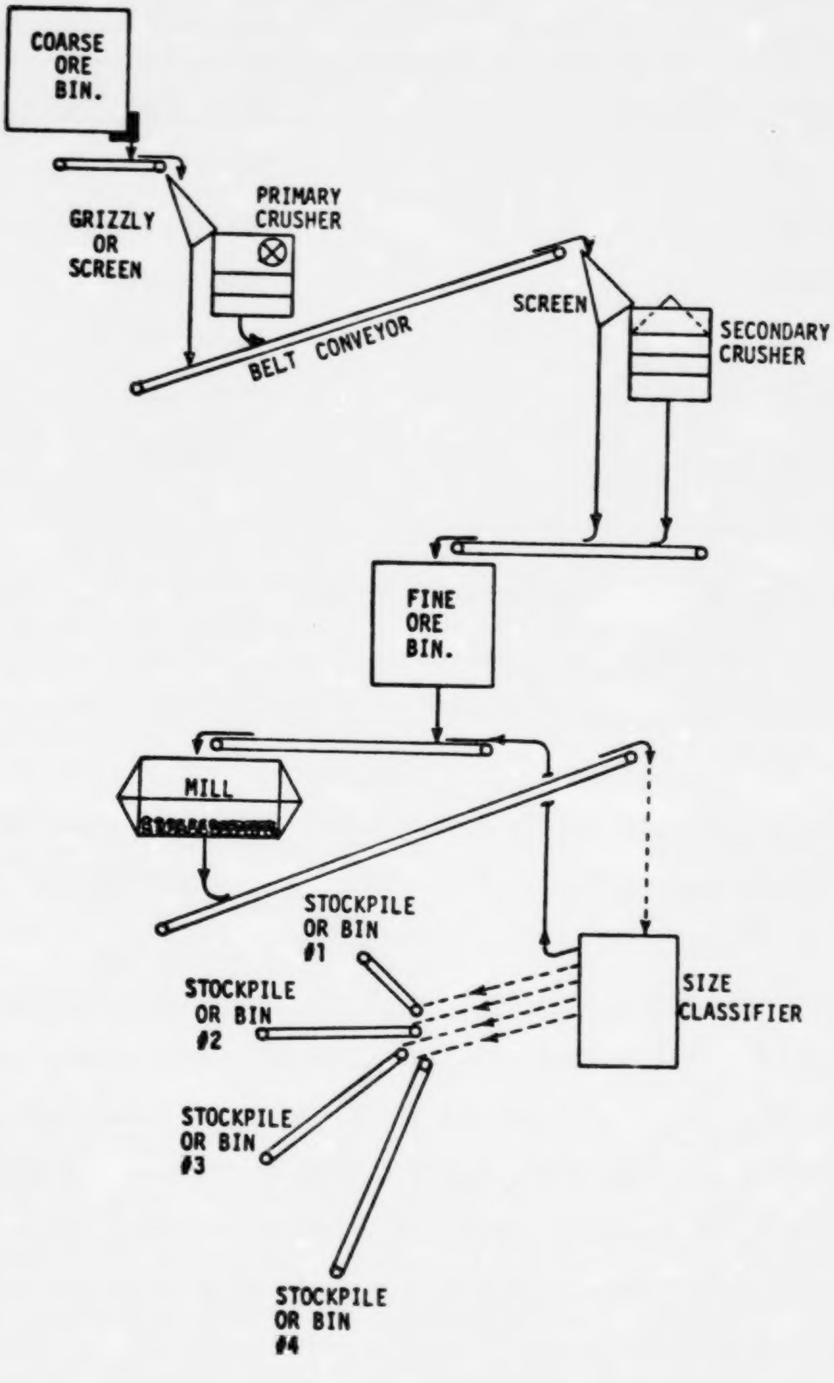

COARSE ORE BIN.
GRIZZLY OR SCREEN
PRIMARY CRUSHER
BELT CONVEYOR
SCREEN
SECONDARY CRUSHER
FINE ORE BIN.
MILL
STOCKPILE OR BIN #1
STOCKPILE OR BIN #2
SIZE CLASSIFIER
STOCKPILE OR BIN #3
STOCKPILE OR BIN #4

Figure 3.2 General Schematic for Non-Metallic Minerals Processing

Table 3.4 EMISSION SOURCES AT NON-METALLIC MINERAL FACILTIES

Fugitive Emissions	Fugitive Dust Sources
Drilling	Blasting
Crushing	Hauling
Screening	Haul Roads
Grinding	Stockpiles
Conveyor Transfer Points	Plant yard
Loading	Conveying

crushed stone plant process operations are presented in Table 3.5. Based on these estimates, fugitive emission sources alone (excluding drilling and fines milling) emit about 5.5 kilograms of dust per megagram of material processed (11 pounds per ton).

The following emission sources are discussed in detail: crushing, screening and conveying operations, grinders, fine product loading and bagging operations. This document will only briefly discuss mining operations.

3.2.2.1 Factors that Affect Emissions from Mining and Process Operations

In general, the factors that affect emissions from most mineral processing operations include: the type of ore processed, the type of equipment and operating practices employed, the moisture content of the ore, the amount of ore processed, and a variety of geographical and seasonal factors. These factors, discussed in more detail below, apply to both fugitive emission and fugitive dust sources associated with mining and processing plant operation.

The type of ore (rock) processed is important. Soft rocks produce a higher percentage of fine-grained material than do hard rocks because of their greater

Table 3.5

Particulate Emission Factors for Stone Crushing Process[4]

Process Operation	Uncontrolled Emission Factor*	
	kg/Mg	lb/ton
Primary crushing	0.25	0.5
Secondary crushing and screening	0.75	1.5
Tertiary crushing and screening (if used)	3.0	6.0
Recrushing and screening	2.5**	5.0
Fines mill	3.0	6.0
Screening, conveying and handling	1.0	2.0

---

* Based on feed to the primary crusher.

** Assume 20 percent undergoes recrushing. Thus, the emission factor becomes 0.5 kg/mg (1.0 lb/ton).

friability and lower resistance to fracture.[5] Thus, it is concluded that the processing of soft rocks results in a greater potential for uncontrolled emissions than the processing of hard rock. Major rock types arranged in order of increasing hardness are: talc, clay, gypsum, barite, limestone and dolomite, perlite, feldspar, and quartz. Thus, talc could be expected to exhibit the highest uncontrolled emissions and quartz the least.

The type of equipment and operating practices employed also affect uncontrolled emissions. In general, emissions from process equipment such as crushers, screens, grinders, and conveyors depend on the size distribution of the material and the velocity that is mechanically imparted to the material. For crushers, the particular type of crushing mechanism employed (compression or impact) affects emissions. The effect of equipment type on uncontrolled emissions from all sources will be more fully discussed in subsequent sections of this report(see Sections 3.2.2.3.1 to 3.2.2.3.5).

The inherent moisture content or wetness of the rock processed can have a substantial effect on uncontrolled emissions. This is especially evident during mining, initial material handling and initial plant process operation such as primary crushing. Surface wetness causes fine particles to agglomorate or adhere to the faces of larger stones with a resultant dust suppression effect. However, as new fine particles are created by crushing and attrition, and as the moisture content is reduced by evaporation, this suppressive effect diminishes and may even disappear. Depending on the geographic and climatic conditions, the moisture content of the mined rock ranges from nearly zero to several percent.

With regard to geographical and seasonal factors, the primary variables affecting uncontrolled particulate emissions are wind parameters and moisture content of the material. Wind parameters will vary with geographical location and season and it can certainly be expected that the level of emissions from sources which are not enclosed (principally fugitive dust sources) will be greater during periods of high winds than periods of low winds. The moisture content of the material will also vary with geographical location and season. It can, therefore, be expected that the level of uncontrolled emissions from both fugitive emission sources and fugitive dust sources will be greater in arid regions of the country than in temperate ones and greater during the summer months due to a higher evaporation rate.

3.2.2.2 Mining Operations

Sources of particulate emissions from mining operations include drilling, blasting, secondary breakage and the loading and hauling of the mineral to the processing plant. Not all non-metallic mineral deposits require drilling and blasting to fragment portions of the deposits into pieces of material of convenient size for further processing. Some mineral deposits can be removed without blasting by the use of power equipment such as front-end loaders, drag lines, and dredges.

Particulate emissions from drilling operations are primarily caused by the removal of cuttings and dust from the bottom of the hole by air flushing. Compressed air is released down the hollow drill center, forcing cuttings and dust up and out the annular space formed between the hole wall and drill.

Blasting is used to displace solid rock from its quarry deposit and to fragment it into sizes which require a minimum of secondary breakage and which can be readily handled by loading and hauling equipment. The frequency of blasting ranges from several shots per day to one per week depending on the plant capacity and the size of individual shots. The effectiveness of a shot depends on the characteristics of the explosive and the rock. Emissions from blasting are evident from visual observations and are largely unavoidable. The emissions generated are affected by the blasting practices employed and are reduced during wet, low wind conditions.

If secondary breakage is required, drop-ball cranes are usually employed. Normally, a pear-shaped or spherical drop-ball, weighing several tons, is suspended by a crane and dropped on the oversize rock as many times as needed to break it. Emissions are slight.

The excavation and loading of broken rock is normally performed by shovels and front-end loaders. Whether the broken rock is dumped into a haulage vehicle for transport or directly into the primary crusher, considerable fugitive dust emissions may result. The most significant factor affecting these emissions is the wetness of the rock.

At most quarries, large capacity "off-the-road" haulage vehicles are used to transport broken rock from the quarry to the primary crusher over unpaved haul roads. This vehicle traffic on unpaved roads is responsible for a large portion of the fugitive dust generated by quarrying operations. Factors affecting fugitive dust emissions from hauling operations include the composition of the road surface, the wetness of the road, and the volume and speed of the vehicle traffic.

3.2.2.3 Processing Plant Facilities and Their Emissions

Principal processing plant facilities include crushers, grinders, screens, and material handling and transfer equipment. As indicated by Table 3.4, all these units are potential sources of particulate emissions. Emissions are generally emitted from process equipment at feed and discharge points and from material handling equipment at transfer points.

3.2.2.3.1 Crushing Operations

Crushing is the process by which coarse material is reduced by mechanical energy and attrition to a desired size for mechanical separation (screening). The mechanical stress applied to rock fragments during crushing may be accomplished by either compression or impact. These two methods of crushing differ in the duration of time needed to apply the breaking force. In impacting, the breaking force is applied very rapidly, while in compression, the rock particle is slowly squeezed and forced to fracture. All types of crushers are both compression and impaction to varying degrees. Table 3.6 ranks crushers according to the predominant crushing mechanism used (from top to bottom, compression to impaction). In all cases, there is some reduction by the rubbing of stone on stone or on metal surfaces (attrition).

TABLE 3.6. RELATIVE CRUSHING MECHANISM UTILIZED BY VARIOUS CRUSHERS[6]

Compression	Double roll crusher
	Jaw crusher
	Gyratory crusher
	Single roll crusher
	Rod mill (low speed)
	Ball mill
	Rod mill (high speed)
	Hammermill (low speed)
	Impact breaker
Impaction	Hammermill (high speed)

The size of the product from compression type crushers is controlled by the space between the crushing surfaces compressing the rock particle. This type of crusher produces a relatively closely graded product with a small proportion of fines. Crushers that reduce by impact, on the other hand, produce a wide range of sizes and a high proportion of fines.

Since the size reduction achievable by one machine is limited, reduction in stages is frequently required. As noted previously, the various stages include primary, secondary, and perhaps tertiary crushing. Basically, the crushers used in the non-metallic minerals industry are: jaw, gyratory, roll and impact crushers.

Jaw Crushers

Jaw crushers consist of a vertical fixed jaw and a moving inclined jaw which is operated by a single toggle or a pair of toggles. Rock is crushed by compression as a result of the opening and closing action of the moveable jaw against the fixed jaw. Their principal application in the industry is for primary crushing.

The most commonly used jaw crusher is the Balke or double-toggle type. As illustrated in Figure 3.3, an eccentric shaft drives a Pitman arm that raises and lowers a pair of toggle plates to open and close the moving jaw which is suspended from a fixed shaft. In a single-toggle jaw crusher, the moving jaw is itself suspended from an eccentric shaft and the lower part of the jaw supported by a rolling toggle plate (Figure 3.4). Rotation of the eccentric shaft produces a circular motion at the upper end of the jaw and an elliptical motion at the lower end. Other types, such as the Dodge and overhead eccentric are used on a limited scale.

The size of a jaw crusher is defined by its feed opening dimensions and may range from about 15 × 30 centimeters to 213 × 168 centimeters (6 × 12 inches to 84 × 66 inches). The size reduction obtainable may range from 3:1 to 10:1 depending on the nature of the rock. Capacities are quite variable

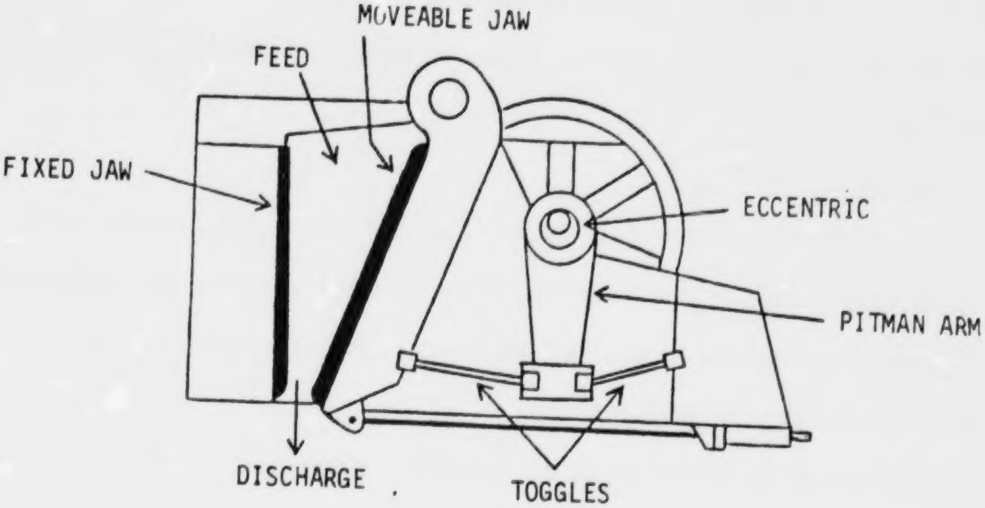

MOVEABLE JAW
FEED
FIXED JAW
ECCENTRIC
PITMAN ARM
DISCHARGE
TOGGLES

Figure 3.3 Double-toggle Jaw Crusher

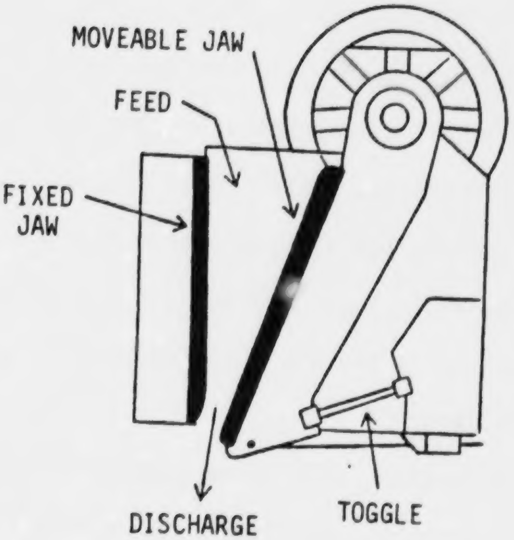

MOVEABLE JAW
FEED
FIXED
JAW
DISCHARGE
TOGGLE

Figure 3.4 Single-toggle Jaw Crusher

depending on the unit and its discharge setting. Table 3.7 presents approximate capacities for a number of jaw crusher sizes at both minimum and maximum discharge settings.

Gyratory Crushers

Simply, a gyratory crusher may be considered to be a jaw crusher with circular jaws between which the material flows and is crushed. As indicated in Table 3.8, however, a gyratory crusher has a much greater capacity than a jaw crusher with an equivalent feed opening.

There are basically three types of gyratory crushers, the pivoted spindle, fixed spindle and cone. The fixed and pivoted spindle gyratories are used for primary and secondary crushing, and cone crushers for secondary and tertiary crushing. The larger gyratories are sized according to feed opening and the smaller units by cone diameters.

The pivoted spindle gyratory (Figure 3.5) has the crushing head mounted on a shaft that is suspended from above and free to pivot. The bottom of the shaft is seated in an eccentric sleeve which revolves, thus causing the crusher head to gyrate in a circular path within a stationary concave circular chamber. The crushing action is similar to that of a jaw crusher in that the crusher element reciprocates to and from a fixed crushing plate. Because some part of the crusher head is working at all times, the discharge from the gyratory is continuous rather than intermittent as in a jaw crusher. The crusher setting is determined by the wide-side opening at the discharge end and is adjusted by raising or lowering the crusher head.

Unlike the pivoted spindle gyratory, the fixed spindle gyratory has its crushing head mounted on an eccentric sleeve fitted over a fixed shaft. This produces a uniform crushing stroke from the top to the bottom of the crushing chamber.

Table 3.7 APPROXIMATE CAPACITIES OF JAW CRUSHERS(7)
(Discharge opening - closed)

Size [cm.(in.)]	Smallest discharge opening [cm.(in.)]	Capacity* [Mg/hr (tons/hr)]	Largest discharge opening [cm.(in.)]	Capacity [Mg/hr (tons/hr)]
91 x 61 (36 x 24)	>6 (3)	68 (75)	15.2 (6)	145 (160)
107 x 152 (42 x 60)	10.2 (4)	118 (130)	20.3 (8)	181 (200)
122 x 107 (48 x 42)	12.7 (5)	159 (175)	20.3 (8)	250 (275)
152 x 122 (60 x 48)	12.7 (5)	218 (240)	22.9 (9)	408 (450)
213 x 168 (84 x 66)	20.3 (8)	363 (400)	30.5 (12)	544 (600)

*Based on rock weighing 1600 kg/m^3 (100 lb/cu ft.)

Table 3.8 APPROXIMATE CAPACITIES OF GYRATORY CRUSHERS (8)
(Discharge opening - open)

Size [cm. (in.)]	Smallest discharge opening [cm.(in.)]	Capacity* [Mg/hr. (tons/hr)]	Largest discharge opening [cm.(in.)]	Capacity [Mg/hr. (tons/hr)]
76 (30)	10.2 (4)	181 (200)	16.5 (6.5)	408 (450)
91 (36)	11.4 (4.5)	336 (370)	17.8 (7)	544 (600)
107 (42)	12.7 (5)	381 (420)	19.1 (7.5)	635 (700)
122 (48)	14.0 (5.5)	680 (750)	22.9 (9)	1088 (1,200)
137 (54)	16.5 (6.5)	816 (900)	24.1 (9.5)	1451 (1,600)
152 (60)	17.8 (7)	1088 (1,200)	25.4 (10)	1814 (2,000)
183 (72)	22.9 (9)	1814 (2,000)	30.5 (12)	2721 (3,000)

*Based on rock weighing 1600 kg/m^3 (100 lb/cu ft.)

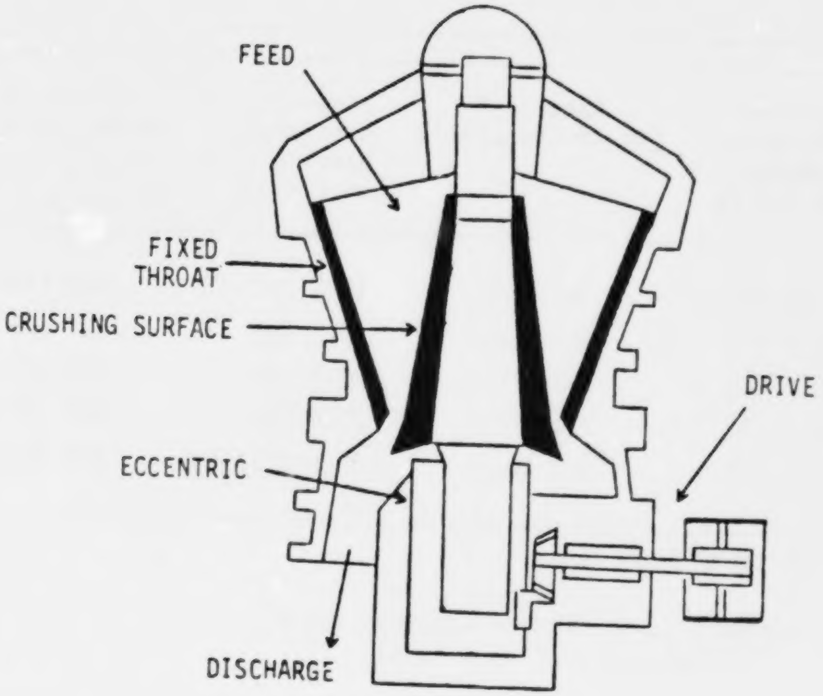


Figure 3.5 The Pivoted Spindle Gyratory

For fine crushing, the gyratory is equipped with flatter heads and converted to a cone crusher (Figure 3.6). Commonly, in the lower section a parallel zone exists. This results in a larger discharge to feed area ratio which makes it extremely suitable for fine crushing at high capacity. Also, unlike regular gyratories, the cone crusher sizes at the closed side setting and not the open side (wide-side) setting. This assures that the material discharge will have been crushed at least once at the closed side setting. Cone crushers yield a cubical product and a high percentage of fines due to interparticle crushing (attrition). They are the most commonly used crusher in the industry for secondary and tertiary reduction. Table 3.9 presents performance data for typical cone crushers.

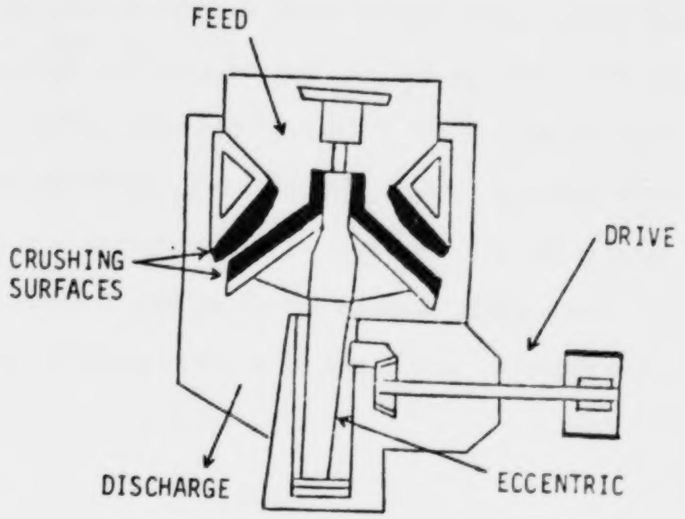


Figure 3.6 Cone Crusher

TABLE 3.9 PERFORMANCE DATA FOR CONE CRUSHERS[9]

Size of crusher (m (ft))	Capacity (Mg/hr (tons/hr)) discharge setting (cm (in))				
	1.0 (3/8)	1.3 (1/2)	1.9	2.5 (1)	3.8 (1.5)
0.6 (2)	18 (20)	23 (25)	23 (25)	-	-
0.9 (3)	32 (35)	36 (40)	64 (70)	-	-
1.2 (4)	54 (60)	73 (80)	109 (120)	136 150	-
1.7 (5.5)	-	-	181 (200)	250 275	308 (340)
2.1 (7)	-	-	229 (330)	408 450	544 (600)

Roll Crushers

These machines are utilized primarily at intermediate or final reduction stages and are often used at portable plants. There are essentially two types, the single-roll and the double-roll. As illustrated in Figure 3.7, the double-roll crusher consists of two heavy parallel rolls which are turned toward each other at the same speed. Roll speeds range from 50 to 300 rpm. Usually, one roll is fixed and the other set by springs. Typically, roll diameters range from 61 to 198 centimeters (24 to 78 inches) and have narrow face widths, about half the roll diameter. Rock particles are caught between the rolls and crushed almost totally by compression. Reduction ratios are limited and range from 3 or 4 to 1. These units produce few fines and no oversize. They are used especially for reducing hard stone to a final product ranging from 1/4 inch to 20 mesh.

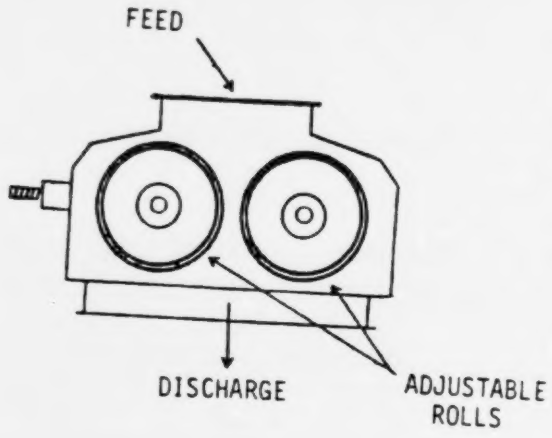


Figure 3.7 Double-roll Crusher

The working elements of a single-roll crusher include a toothed or knobbed roll and a curved crushing plate which may be corrugated or smooth. The crushing plate is generally hinged at the top and its setting is held by a spring at the bottom. A toothed-roll crusher is depicted in Figure 3.8. The feed caught between the roll and crushing plate is broken by a combination of compression, impact and shear. These units may accept feed sizes up to

51 centimeters (20 inches) and have capacities up to 454 megagrams per hour (500 tons/hr). In contrast with the double-roll, the single-roll crusher is principally used for reducing soft materials such as limestones.

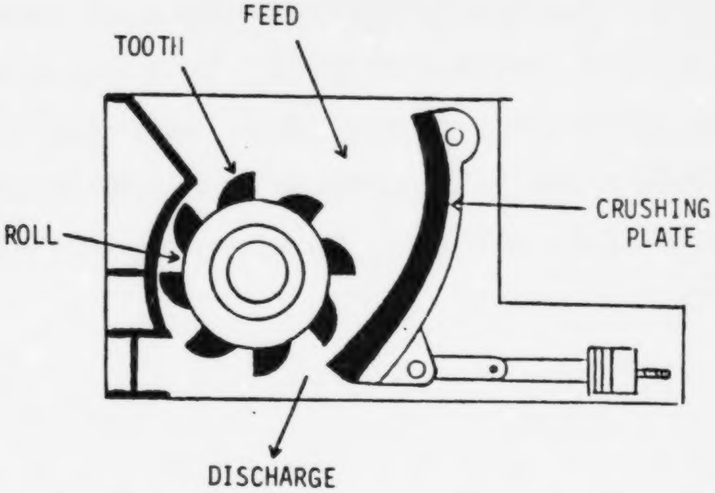


Figure 3.8 Single roll Crusher

Impact Crushers

Impact crushers, including hammermills and impactors, use the force of fast rotating massive impellers or hammers to strike and shatter free falling rock particles. These units have extremely high reduction ratios and produce a cubical product spread over a wide range of particle sizes with a large proportion of fines, thus making their application in industry segments such as cement manufacturing and agstone production extremely cost effective by reducing the need for subsequent grinding machines.

A hammermill consists of a high speed horizontal rotor with several rotor discs to which sets of swing hammers are attached (Figure 3.9). As rock particles are fed into the crushing chamber, they are impacted and shattered by the hammers which attain tangential speeds as high as 76 meters (250 feet) per second. The shattered rock then collides with a steel breaker plate and is fragmented even further. A cylindrical grating or screen positioned at the discharge opening restrains oversize material until it is reduced to a size small enough to pass between the grate bars. Rotor speeds range from 250 to 1800 rpm and capacities to over 907 megagrams per hour (1,000 tons/hr). Product size is controlled by the rotor speed, the spacing between the grate bars, and by hammer length.

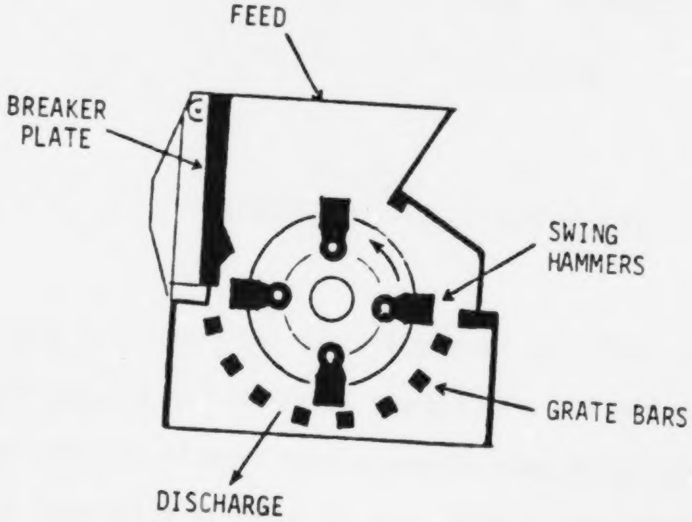


Figure 3.9 Hammermill

An impact breaker (Figure 3.10) is similar to a hammermill except that it has no grate or screen to act as a restraining member. Feed is broken by impact alone. Adjustable breaker bars are used instead of plates to reflect material back into the path of the impellers. Primary-reduction units are available which can reduce quarry run material at over 907 megagrams per hour (1,000 tons/hr) capacity to about 2.5 centimeters (1 inch). These units are not appropriate for hard abrasive materials, but are ideal for soft rocks like limestone.

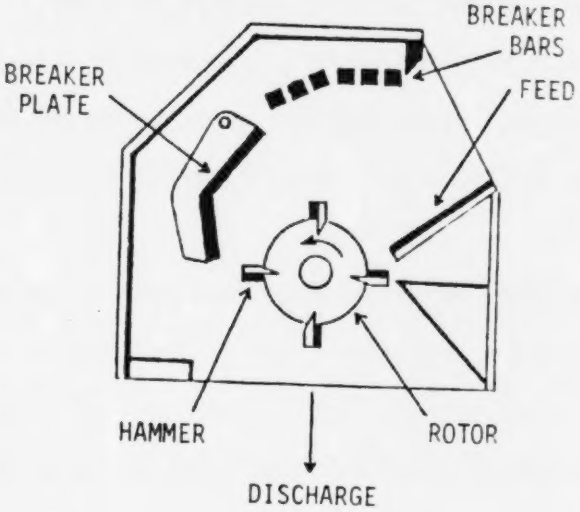


Figure 3.10 Impact Crusher

Sources of Emissions

The generation of particulate emissions is inherent in the crushing process. Emissions are most apparent at crusher feed and discharge points. Emissions are influenced predominantly by the type of rock processed, the moisture content of the rock, and the type of crusher used.

The most important element influencing emissions from crushing equipment, as previously mentioned, is the type of rock and the moisture content of the mineral being crushed. The crushing mechanism employed has a substantial affect on the size reduction that a machine can achieve; the particle size distribution of the product, especially the proportion of fines produced; and the amount of mechanically induced energy which is imparted to fines.

Crushing units utilizing impact rather than compression produce a larger proportion of fines as noted above. In addition to generating more fines, impact crushers also impact higher velocity to them as a result of the fan-like action produced by the fast rotating hammers. Because of this and the high proportion of fines produced, impact crushers generate larger quantities of uncontrolled particulate emissions per ton of material processed than any other crusher type.

The level of uncontrolled emissions from jaw, gyratory, cone and roll crushers closely parallels the reduction stage to which they are applied. As indicated in Table 3-5, emissions increase progressively from primary to secondary to tertiary crushing. Factors other than the type of crushing mechanism (compression, impact) also affect emissions. In all likelihood, primary jaw crushers produce greater emissions than comparable gyratory because of the bellows effect of the jaw and because gyratory crushers are usually choke fed to minimize the open spaces from which dust may be emitted. For subsequent reduction stages, cone crushers produce more fines as a result of attrition and consequently generate more dust.

3.2.2.3.2 Screening Operations

Screening is the process by which a mixture of stones is separated according to size. In screening, material is dropped into a mesh surface with openings of desired size and separated into two fractions, undersize which passes through the screen opening and oversize which is retained on the screen surface. When material is passed over and through multiple screening surfaces, it is separated into fractions of known particle size distribution. Screening surfaces may be constructed of metal bars, perforated or slotted metal plates, or woven wire cloth.

The capacity of a screen is primarily determined by the open area of the screening surface and the physical characteristics of the feed. It is usually expressed in tons of material per hour per square foot of screen area. Although screening may be performed wet or dry, dry screening is the more common.

Screening equipment commonly used in the non-metallic minerals industry includes grizzlies, shaking screens, vibrating screens, and revolving screens.

Grizzlies

Grizzlies consist of a set of uniformly spaced bars, rods or rails. The bars may be horizontal or inclined and are usually wider in cross section at the top than the bottom. This prevents the clogging or wedging of stone particles between bars. The spacing between the bars ranges from 5 to 20 centimeters (2 to 8 inches). Bars are usually constructed of manganese steel or other highly abrasion-resistant material.

Grizzlies are primarily used to remove fines prior to primary crushing, thus reducing the load on the primary crusher. Grizzlies may be stationary cantilevered (fixed at one end with the discharge end free to vibrate) or mechanically vibrated. Vibrating grizzlies are simple bar grizzlies mounted on eccentrics (Figure 3-11). The entire assembly is moved forward and backward at about 100 strokes a minute, resulting in better flow through and across the grizzly surface.

Shaking Screens

The shaking screen consists of a rectangular frame with perforated plate or wire cloth screening surfaces, usually suspended by rods or cables and inclined at an angle of 14 degrees. The screens are mechanically shaken parallel to the plane of material flow at speeds ranging from 60 to 800 strokes per minute and at amplitudes ranging from 2 to 23 centimeters (3/4 to 9 inches).[10] Generally, they are used for screening coarse material, 1.3 centimeters (1/2-inch) or larger.

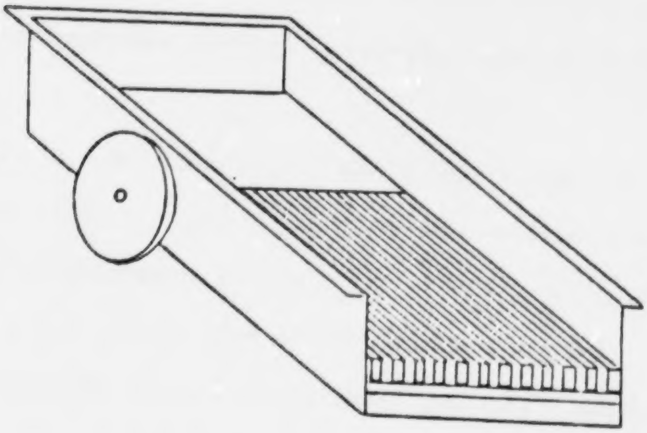


Figure 3.11 Vibrating Grizzly

Vibrating Screens

Where large capacity and high efficiency are desired, the vibrating screen has practically replaced all other screen types. It is by far the most commonly used screen type in the non-metallic minerals industry. A vibrating screen (Figure 3.12) essentially consists of an inclined flat or slightly convex screening surface which is rapidly vibrated in a plane normal or nearly normal to the screen surface. The screening motion is of small amplitude but high frequency, normally in excess of 3,000 cycles per minute. The vibrations may be generated either mechanically by means of an eccentric shaft, unbalanced fly wheel, cam and tappet assembly, or electrically by means of an electromagnet.

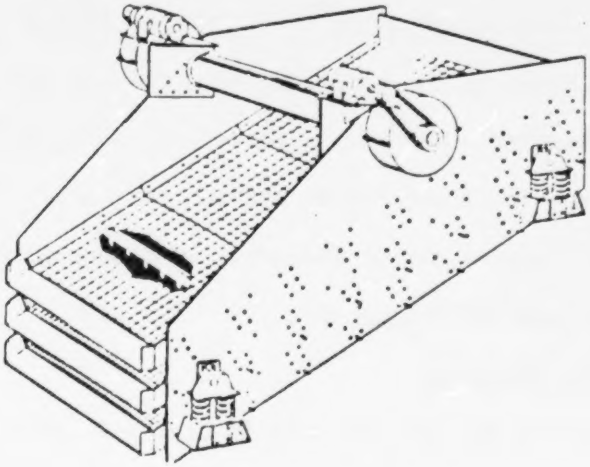


Figure 3.12 Vibrating Screen

Mechanically-vibrated units are operated at about 1,200 to 1,800 rpm and at amplitudes of about 0.3 to 1.3 centimeters (1/8 to 1/2 inch). Electrically vibrated screens are available in standard sizes from 30 to 180 centimeters (12 inches to 6 feet) wide and 0.76 to 6.1 meters (2-1/2 to 20 feet) long. A complete screening unit may have one, two or three decks.

Revolving Screens

This screen type consists of an inclined cylindrical frame around which is wrapped a screening surface of wire cloth or perforated plate. Feed material is delivered at the upper end and, as the screen is rotated, undersized material passes through the screen openings while the oversized is discharged at the lower end. Revolving screens are available up to 1.2 meters (4 feet) in diameter and usually run at 15 to 20 rpm.[11]

Source of Emissions

Dust is emitted from screening operations as a result of the agitation of dry material. The level of uncontrolled emissions depends on the quantity of fine particles contained in the material, the moisture content of the material and the type of screening equipment. Generally, the screening of fines produces higher emissions than the screening of coarse materials. Also, screens agitated at large amplitudes and high frequency emit more dust than those operated at small amplitudes and low frequencies.

3.2.2.3.3 Conveying Operation

Materials handling devices are used to convey materials from one point to another. The most common include feeders, belt conveyors, bucket elevators, screw conveyors, and pneumatic systems.

Feeders

Feeders are relatively short, heavy-duty conveyance devices used to receive material and deliver it to process units, especially crushers, at a uniform regulated rate. The various types used are the apron, belt, reciprocating plate, vibrating, and wobbler feeders.

Apron feeders are composed of overlapping metal pans or aprons which are hinged or linked by chains to form an endless conveyor supported by rollers and spaced between a head and tail assembly. These feeders are constructed to withstand high impact and abrasion and are available in various widths (18 to 27 inches) and lengths.

Belt feeders are essentially short, heavy duty belt conveyors equipped with closely spaced support rollers. Adjustable gates are used to regulate feed rates. Belt feeders are available in 46 to 122 centimeter (18 to 48 inch) widths and 0.9 to 3.7 meter (3 to 12 foot) lengths and are operated at speeds of 12.2 to 30.5 meters (40 to 100 feet) per minute.

Reciprocating plate feeders consist of a heavy-duty horizontal plate which is driven in a reciprocating motion causing material to move forward at a uniform rate. The feed rate is controlled by adjusting the frequency and length of the stroke.

Vibrating feeders operate at a relatively high frequency and low amplitude. Their feed rate is controlled by the slope of the feeder bed and the amplitude of the vibrations. These feeders are available in a variety of sizes, capacities and drives. When combined with a grizzly, both scalping and feeding functions are performed.

Wobbler feeders also perform the dual task of scalping and feeding. These units consist of a series of closely spaced elliptical bars which are mechanically rotated, causing oversize material to tumble forward to the discharge and undersize material to pass through the spaces. The feed rate is controlled by the bar spacing and the speed of rotation.

Belt Conveyors

Belt conveyors are the most widely used means of transporting, elevating and handling materials in the non-metallic minerals industry. As illustrated in Figure 3.13, belt conveyors consist of an endless belt which is carried on a series of idlers usually arranged so that the belt forms a trough. The belt is stretched between a drive or head pulley and a tail pulley. Although belts may be constructed of other material, reinforced rubber is the most commonly used. Belt widths may range from 36 to 152 centimeters (14 to 60 inches) with 76 to 91 centimeter (30 to 36 inch) belts the most common. Normal operating speeds may range from 60 to 120 meters per minute (200 to 400 feet/minute).

Depending on the belt speed, belt width and rock density, load capacities may be in excess of 1360 megagrams (1,500 tons) per hour.

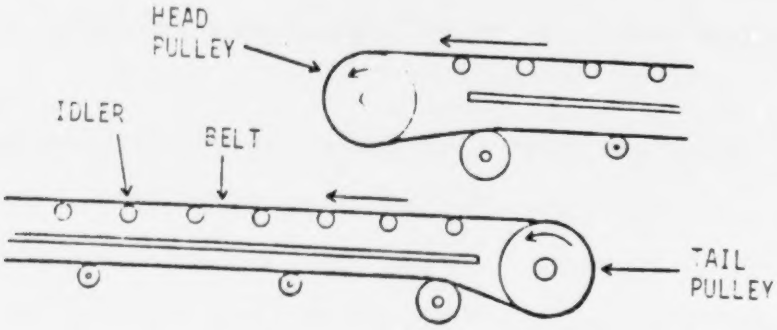


Figure 3.13 Conveyor Belt Transfer Point

Elevators

Bucket elevators are utilized where substantial elevation is required within a limited space. They consist of a head and foot assembly which supports and drives an endless single or double strand chain or belt to which buckets are attached. Figure 3.14 depicts the three types most commonly used: the high-speed centrifugal-discharge, the slow speed positive or perfect-discharge, and the continuous-bucket elevator.

The centrifugal-discharge elevator has a single strand of chain or belt to which the spaced buckets are attached. As the buckets round the tail pulley, which is housed within a suitable curved boot, the buckets scoop up their load and elevate it to the point of discharge. The buckets are so spaced so that at discharge, the material is thrown out by the centrifugal action of the bucket rounding the head pulley. The positive-discharge type also utilizes spaced buckets but differs from the centrifugal type in that it has a

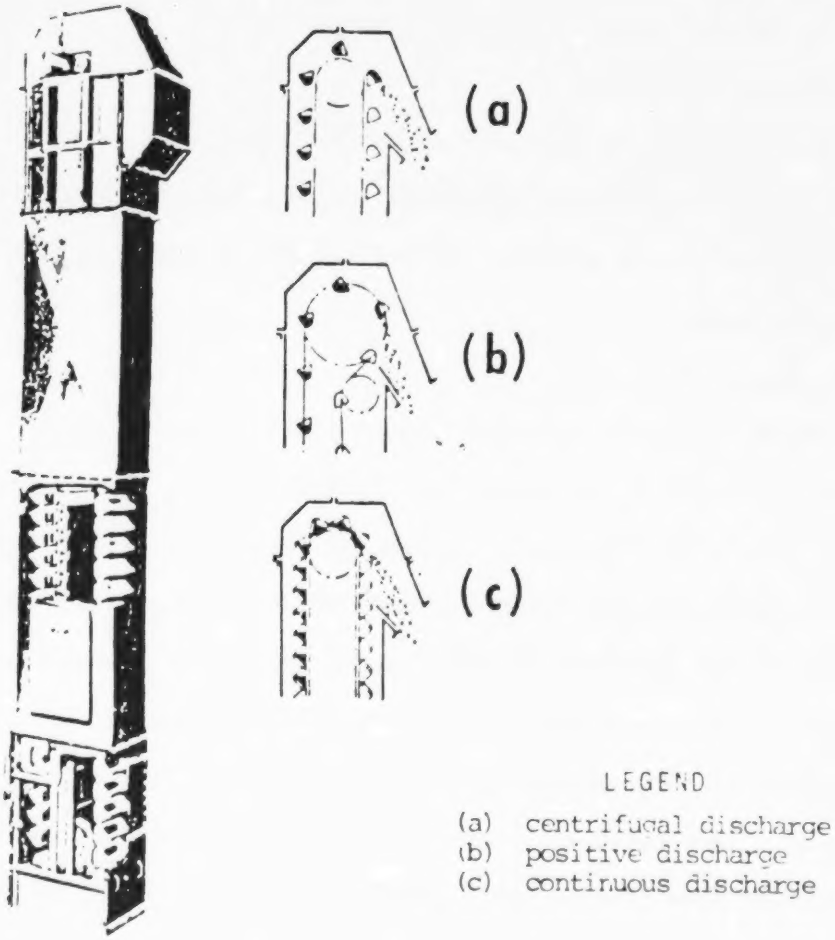

(a)
(b)
(c)
LEGEND
(a) centrifugal discharge
(b) positive discharge
(c) continuous discharge

Figure 3.14. Bucket Elevator Types

double-strand chain and a different discharge mechanism. An additional sprocket, set below the head pulley, effectively bends the strands back under the pulley causing the bucket to be totally inverted resulting in a positive discharge.

The continuous-bucket elevator utilizes closely spaced buckets attached to single or double strand belt or chain. Material is loaded directly into the buckets during ascent and is discharged gently as a result of using the back of the precluding bucket as a discharge chute.

Screw Conveyors

Screw conveyors are comprised of a steel shaft with a spiral or helical fin which, when rotated, pushes material along a trough. Since these conveyors are usually used with wet classification, no significant emission problem is experienced.

Pneumatic Conveyors

Pneumatic conveyors are comprised of tubes or ducts through which material is conveyed. Pneumatic conveyors are divided into two classes termed by their operating principles: pressure systems and vacuum (suction) systems.

Pressure systems are further classified into low pressure and high pressure types, and vacuum systems into low-, medium-, and high-vacuum types. Pressure and vacuum systems occasionally are used in combination for special requirements.

Pressure systems operate at pressure obtainable from a fan (low-pressure systems) or a compressed air system (high-pressure systems). Normally, the airstream functions in a 20 to 31 centimeter (8 inch to 12 inch) diameter pipeline. Into this line, material is fed from a hopper or other device at controlled rates. The airstream immediately suspends this material and conveys it to a cyclone-type or filter-type collector for deposit. Conveying air escapes via the cyclone vent or through the filter.

Vacuum systems offer the advantage of clean, efficient pickup from railcars, trucks or bins for unloading or in-plant conveying operations. Cyclone receivers or combination receiver-filters are used at the terminal of the system to separate the material being conveyed from the air. Below the receiver, either a rotary feeder or gatelock (trap door feeder) is employed as a discharge air lock. Positive displacement blowers are used as exhausters to provide the necessary conveying air at the operating vacuum. Generally, the vacuum system is most applicable where the feed-in point must be flexible, such as unloading railroad cars, barges, ships, or reclaiming material from open warehouse storage, or where it is desirable to pick up material from a multiplicity of stations.

Source of Emissions

Particulates may be emitted from any of the material handling and transfer operations. As with screening, the level of uncontrolled emissions depends on the material being handled, the size of the material handled, the degree of agitation of the material and the moisture content of the material. Perhaps the largest emissions occur at conveyor belt transfer points. Depending on the conveyor belt speed and the free fall distance between transfer points, substantial emissions may be generated

3.2.2.3.4 Grinding Operation

Grinding is a further step in the reduction of material to particle sizes smaller than those attainable by crushers. Because the material to be treated has already been reduced to small sizes, and the force to be applied to each particle is comparatively small, the machines used in grinding are of a different type, and may operate on a different principle, from those used in more coarse crushing.

As with crushers, the most important element influencing emissions from grinding mills is the reduction mechanism employed, compression or impact. Grinding mills generally utilize impact rather than compression. Reduction by impact will produce a larger proportion of fines. Particulate emissions are generated from grinding mills at the grinder's inlet and outlet. Gravity type grinding mills accept feed from a conveyor and discharge product into a screen or classifier or onto a conveyor. These transfer points are the source of particulate emissions. The outlet has the highest emissions potential because of the finer material. Air-swept mills include an air conveying system and an air separator, a classifier, or both. The air separator and and classifier are generally cyclone collectors. In some systems, the air just conveys the material to a separator for deposit into a storage bin with the conveying air escaping via the cyclone vent. In other grinding systems, the air is continuously recirculated. Maintaining this circulating air system under suction keeps the mill dustless in operation, and any surplus air drawn into the system due to the suction created by the fan is released through a vent. In both cases the vent gases will contain a certain amount of particulate matter.

The levels of uncontrolled emissions from grinding mills (fine mills) are indicated in Table 3-5.

Many types of grinding mills are manufactured for use by various industries. The principal types of mills used are: (1) hammer, (2) roller, (3) rod, (4) pebble and ball, and (5) fluid energy. Each of these types of mills is discussed separately below.

Hammermills

A hammermill consists of a high speed horizontal rotor with several rotor discs to which sets of swing hammers are attached. As rock particles are fed into the grinding chamber, they are impacted and shattered by the hammers which attain peripheral speeds greater than 4,572 meters per minute (250 feet per second). The shattered rock then collides with a steel breaker plate and is fragmented even further. A cylindrical grating or screen positioned at the discharge opening restrains oversize material until it is reduced to a size small enough to pass between the grate bars. Product size is controlled by the rotor speed, the spacing between the grate bars, and by hammer length. These mills are used for nonabrasive materials and can accomplish a size reduction of up to 12:1.

Roller Mill

The roller mill, also known as a Raymond Roller Mill, with its integral whizzer separator can produce ground material ranging from 20 mesh to 325 mesh or finer. The material is ground by rollers that travel along the inside of a horizontal stationary ring. The rollers swing outward by centrifugal force, and trap the material between them and the ring. The material is swept out of the mill by a stream of air to a whizzer separator, located directly on top of the mill, where the oversize is separated and dropped back for further grinding while the desired fines pass up through the whizzer blades into the duct leading to the air separator (cyclone). A typical roller mill is shown in Figure 3.15.

Rod Mill

The rod mill is generally considered as a granular grinding unit, principally for handling a maximum feed size of 2 to 4 centimeters (1 to 2 inches),

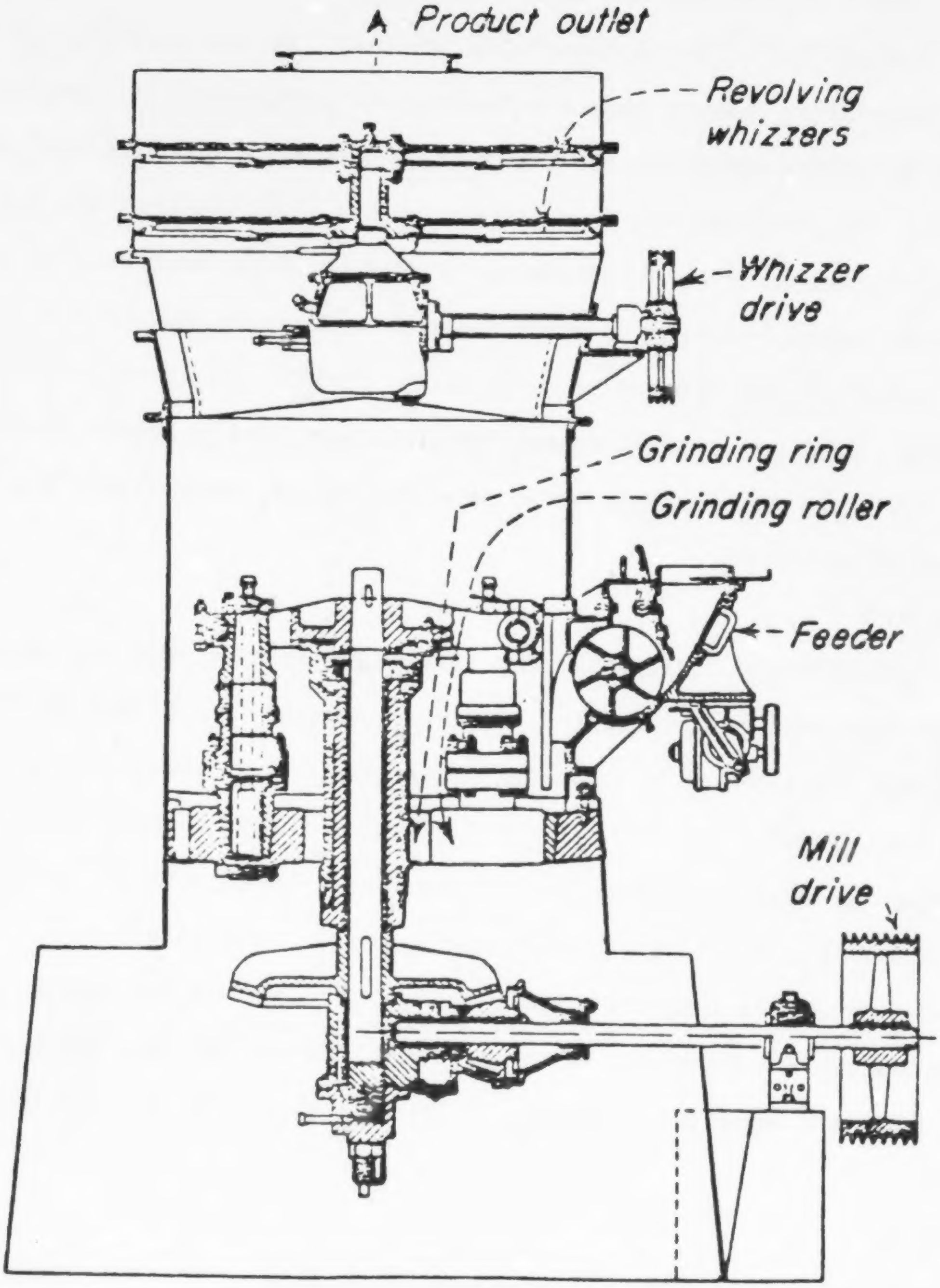

Product outlet
Revolving whizzers
Whizzer drive
Grinding ring
Grinding roller
Feeder
Mill drive

Figure 3.15. Roller Mill

and grinding to a maximum of 65 mesh. It is normally used in a closed circuit with a sizing device, such as classifiers or screens, and for wet or dry grinding. It will grind with the minimum of the finer sizes, such as 100 or 200 mesh, and will handle relatively high moisture material without packing.

The mill in its general form consists of a horizontal, slow-speed, rotating, cylindrical drum. The grinding media consists of a charge of steel rods, slightly shorter than the mill's inside length and from 5 to 13 centimeters (2 inches to 5 inches) in diameter. The rods roll freely inside the drum during its rotation to give the grinding action desired.

Pebble and Ball Mills

The simplest form of a ball mill is cylindrical, horizontal, slow-speed rotating drum containing a mass of balls as grinding media. When other types of grinding media such as a flint or various ceramic pebbles are used, it is known as a pebble mill. The ball mill uses steel, flint, porcelain, or cast iron balls. A typical ball mill is shown in Figure 3.16.

The diameter of balls or pebbles as the initial charge in a mill is determined by the size of the feed material and the desired fineness of the product. Usually the larger diameter ranges are used for preliminary grinding and the smaller for final grinding. Ball mills reduce the size of the feed mostly by impact. These grinders normally have a speed of 10 to 40 revolutions per minute. If the shell rotates too fast, centrifugal force keeps the balls against the shell and minimal grinding occurs.

Fluid Energy Mills

When the desired material size is in the range of 1 to 20 microns, an ultrafine grinder such as the fluid energy mill is required. A typical fluid energy mill is shown in Figure 3.17. In this type of mill, the particles are

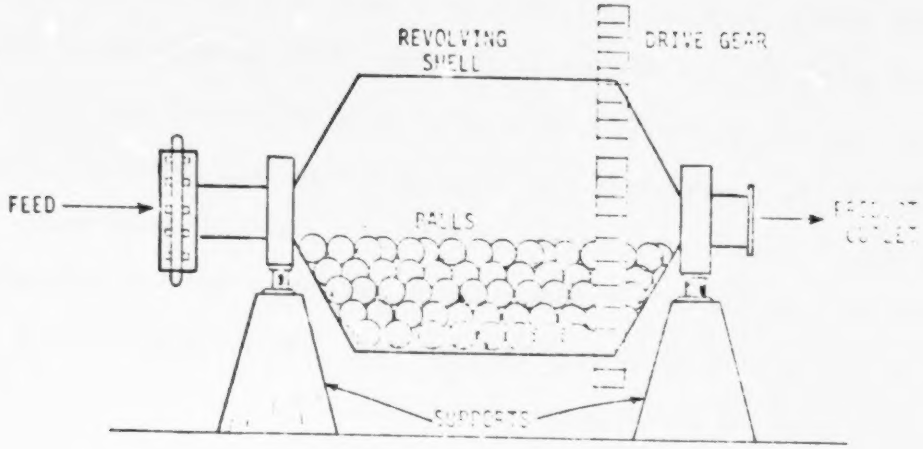

REVOLVING SHELL
DRIVE GEAR
FEED
BALLS
PRODUCT OUTLET
SUPPORTS

Figure 3.16. Ball Mill

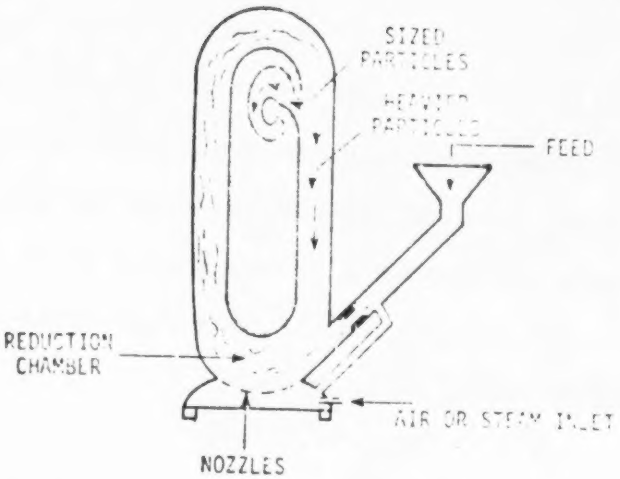

SIZED PARTICLES
HEAVIER PARTICLES
FEED
REDUCTION CHAMBER
AIR OR STEAM INLET
NOZZLES

Figure 3.17. Fluid-energy Mill

suspended and conveyed by a high velocity gas stream in a circular or elliptical path. Size reduction is caused by impaction and rubbing against mill walls, and by interparticle attrition. Classification of the particles takes place at the upper bend of the loop shown in Figure 3.17. Internal classification occurs because the smaller particles are carried through the outlet by the gas stream while the larger particles are thrown against the outer wall by centrifugal force. Product size can be varied by changing the gas velocity through the grinder.

Fluid energy mills can normally reduce up to 0.91 megagrams/hr (1 t/hr) of solids from 0.149 mm (100 mesh) to particles averaging 1.2 to 10 microns in diameter. Typical gas requirements are 0.45 and 1.8 kg (1 to 4 pounds) of steam or 2.7 to 4.1 kg (6 to 9 pounds) of air admitted at about 6.8 atm (100 psig) per 0.45 kg (1 pound) of product. The grinding chambers are about 2.5 to 20 cm (1 to 8 inches) in diameter and the equipment is 1.2 to 2.4 meters (4 to 8 feet) high.

Separating and Classifying

Mechanical air separators of the centrifugal type cover a distinct field and find wide acceptance for the classification of dry materials in a relatively fine state of subdivision. In commercial practice the separator may be said to begin where the impact of vibrating screens leave off,[12] extending from about 40 to 60 mesh down.

Briefly stated, the selective action of the centrifugal separator is the result of an ascending air current generated within the machine by means of a fan, such current tending to lift the finer particles against the combined effect of centrifugal force and gravity. In operation the feed opening allows the material to drop on the lower or distributing plate where it is spread and thrown off by centrifugal force, the larger and heavier particles being projected against an inner casing, while the smaller and lighter particles are picked up by the ascending air current created by the fan. These fines are carried over into an outer cone and deposited. Concurrently, the rejected coarse material drops into the inner cone, passes out through a spout and is recycled back to the grinding mill.

The air, after dropping the major portion of its burden, is either recirculated back to the grinding mill or vented. In the case of the recirculated air, a small amount of extraneous air is entrained in the feed and frequently builds up pressure in the separator, in which case the excess air may be vented off. Both vent gases are a source of particulate matter.

3.2.2.3.5 Bagging and Bulk Loading Operations

In the non-metallic minerals industry the valve type paper bag, either sewn or pasted together, is widely used for shipping fine materials. The valve bag is "factory closed," that is, the top and bottom are closed either by sewing or by pasting, and a single small opening is left on one corner. Materials are discharged into the bag through the valve. The valve closes automatically due to the internal pressure of the contents of the bag as soon as it is filled.

The valve type bag is filled by means of a packing machine designed specifically for this purpose. The material enters the bag through a nozzle inserted in the valve opening, and the valve closes automatically when the filling is completed.

Bagging operations are a source of particulate emissions. Dust is emitted during the final stages of filling when dust laden air is forced out of the bag. The fugitive emissions due to bagging operation are generally localized in the area of the bagging machine.

Fine product materials that are not bagged for shipment are either bulk loaded in tank trucks or enclosed railroad cars. The usual method of loading is gravity feeding through plastic or fabric sleeves. Bulk loading of fine material is a source of particulate because, as in the bagging operation, dust laden air is forced out of the truck or railroad car during the loading operation.

3.2.3 Emissions Under Existing Regulations

Existing State regulations applicable to the non-metallic minerals industry take many forms, depending on whether emissions are process or fugitive in nature. Regulations limiting particulate emissions from process sources are based on general process weight, concentration and/or visible emission regulations. For a 45 megagrams per hour (50 t/hr) plant, typical process weight regulations would limit allowable emissions from each process step (i.e., crushing, grinding, drying) to 25.6 kg/hr (56.4 lb/hr).[13] This is about 95 percent reduction in uncontrolled emissions. For a typical 454 megagrams per hour (500 t/hr) crushing plant, most stringent and least stringent process weight regulations would limit allowable emissions to 18.2 and 120 kg/hr (40.0 and 264.0 lb/hr), respectively. The most stringent regulations, such as Pennsylvania's, limit emission from a collection device to 0.09 g/dscm (0.04 gr.dscf) and in some cases to as low as 0.046 g/dscm (0.02 gr/dscf).[14]

Fugitive dust regulations are for the most part subjective and vague. Most suggest that reasonable precautions be taken for control, but provide no means of determining compliance. Some states prohibit fugitive dust or emissions from any source from crossing property boundaries either by disallowing any visible emissions or limiting them with an ambient concentration standard.

REFERENCES

1. Minerals Yearbook (1972), Volume I, Bureau of Mines.

2. Development Document for Interim Final Effluent Limitations Guidelines and New Source Performance Standards for the Mineral Mining and Processing Industry, U.S. Environmental Protection Agency, October 1975.

3. Commodity Data Summaries Annual, 1977, U.S. Bureau of Mines.

4. Compilation of Air Pollution Emission Factors, Second Edition, U.S. Environmental Protection Agency, Publication No. AP-42, April 1973, p. 8.20-1.

5. Characterization of Particulate Emissions from the Stone-Processing Industry, Research Triangle Institute, EPA Contract No. 68-02-0607, May 1975, p. 57.

6. Pit and Quarry Handbook and Purchasing Guide. 63rd Edition, Pit and Quarry Publications, Incorporated, Chicago, 1970, p. B-17.

7. Reference 6.

8. Reference 6.

9. Perry, Robert H. (editor), Chemical Engineers Handbook, 5th Edition, McGraw-Hill, New York, 1973, p. 8-21.

10. Reference 9, p. 956.

11. Reference 6, p. B-144.

12. Reference 6, p. B-73.

13. Analysis of Final State Implementation Plans-Rules and Regulations, prepared by the MITRE Corporation for the U.S. Environmental Protection Agency, Contract No. 68-02-0248, July 1972.

14. Title 25. Rules and Regulations, Pennsylvania Department of Environmental Resources, pages 123.2-123.3.

4. EMISSION CONTROL TECHNIQUES

The diversity of the particulate emission sources involved in mining and processing non-metallic minerals requires use of a variety of control methods and techniques. Dust suppression techniques, designed to prevent particulate matter from becoming airborne, are applicable to both fugitive process and fugitive dust sources. Where particulate emissions can be contained and captured, particulate collection systems are used. Emission sources and applicable control options are listed in Table 4.1.

This chapter discusses the control technology applicable to the following process operations at non-metallic minerals plants: crushers, grinders, screens, conveyor transfer points, storage bins, and fine products loading and bagging.

4.1 CONTROL OF PLANT PROCESS OPERATIONS

A representative non-metallic mineral processing plant, consisting of crushers; grinders; screens; conveyor transfer points; and storage, loading and bagging facilities, contains a multiplicity of dust-producing points. Therefore, effective emission control can present a number of problems. Methods utilized to reduce emissions include wet dust suppression, dry collection, and a combination of the two. Wet dust suppression consists of introducing moisture into the material flow, causing fine particulate matter to be confined and remain with the material flow rather than becoming airborne. Dry collection involves hooding and enclosing dust-producing points and exhausting emissions to a collection device. Combination systems utilize

Table 4.1. PARTICULATE EMISSION SOURCES FOR THE EXTRACTION AND PROCESSING OF NON-METALLIC MINERALS

Operation or Source[a]	Control Options
Drilling	a) Liquid injection (water or water plus a wetting agent) b) Capturing and venting emissions to a control device
Blasting	Adopt good blasting practices
Loading (at mine)	Water wetting
Hauling	a) Water wetting of haulage roads b) Treatment of haulage roads with surface agents c) Soil stabilization d) Paving e) Traffic control
Crushing	a) Wet dust suppression systems b) Capturing and venting emissions to a control device
Screening	Same as crushing
Conveying (transfer points)	Same as crushing
Stockpiling	a) Stone ladders b) Stacker conveyors c) Water sprays at conveyor discharge d) Pugmill
Grinding	Same as crushing
Storage Bins	Capturing and Venting to a control device
Conveying (other than transfer points)	a) Covering b) Wet dust suppression
Windblown dust from stockpiles	a) Water wetting b) Surface active agents c) Covering (i.e., silos, bins) d) Windbreaks
Windblown dust from roads and plant yard	a) Water wetting b) Oiling c) Surface active agents d) Soil stabilization e) Paving f) Sweeping

Table 4.1 (Continued)

Operation or Source[a]		Control Options
Loading (product into RR cars, trucks, ships)	a)	Wetting
	b)	Capturing and venting to control device
Bagging	a)	Capturing and venting to control device
Magnetic Separation	a)	Capturing and Venting to control device

---

[a] Does not include processes involving combustion

both methods at different stages throughout the processing plant. In addition to these control techniques, the use of enclosed structures to house process equipment may also be effective in preventing emissions to the atmosphere.

4.1.1 Wet Dust Suppression

In a wet dust suppression system, dust emissions are controlled by applying moisture in the form of water or water plus a wetting agent sprayed at critical dust producing points in the process flow. This causes dust particles to adhere to larger mineral pieces or to form agglomerates too heavy to become or remain airborne. Thus, the objective of wet dust suppression is not to fog an emission source with a fine mist to capture and remove particulates emitted, but rather to prevent their emission by keeping the material moist at all process stages.

The wet dust suppression method has been used on a wide variety of stone including limestone, traprock, granite, shale, dolomite, and sand and gravel. It can be generally considered to have a universal application to stone handled through a normal crushing and screening operation. In some cases, however, watersprays cannot be used since the moisture may interfere with further processing such as crushing, screening or grinding where blinding problems may occur. In addition, the capacity of the dryers used in some of the processing steps limits the amount of water that can be sprayed onto the raw materials. Once the materials have passed through the drying operations, water cannot be added and other means of dust control must be utilized.

When plain or untreated water is used, because of its unusually high surface tension (72.75 dynes/cm^2 at 20°C), the addition of 5 to 8 percent moisture (by weight), or greater, may be required to adequately suppress dust.[1] In many installations this may not be acceptable because excess moisture may cause screening surfaces to blind, thus reducing both their capacity and effectiveness, or result in the coating of mineral surfaces yielding a marginal or non-specification product. To counteract these deficiencies, small quantitites of specially formulated wetting agents or surfactants are blended with the water to reduce its surface tension and consequently improve its wetting efficiency so that dust particles may be suppressed with a minimum of added moisture. Although these agents may vary in composition, their molecules are characteristically composed of two groups, a hydrophobic group (usually a long chain hydrocarbon) and a hydrophilic group (usually a sulfate, sulfonate, hydroxide or ethylene oxide). When introduced into water, these agents effect an appreciable reduction in its surface tension (to as low as 27 dynes/cm^2).[2] The dilution of such an agent in minute quantities in water (1 part wetting agent to 1,000 parts water) is reported to make dust control practical throughout an entire crushing plant. In a crushed stone plant, this may amount to as little as 1/2 to 1 percent total moisture per ton of stone processed.[3]

In adding moisture to the process material, several application points are normally required. Since the time required for the proper distribution of the added moisture on the mineral is critical to achieving effective dust control, treatment normally begins as soon as possible after the material to be processed is introduced into the plant. As such, the initial application point is commonly made at the primary crusher truck dump. In addition to introducing moisture prior to processing, this application contributes to reducing intermittent dust emissions generated during dumping operations. Spray bars located either on the periphery of the dump hopper or above it are used. Applications are also made at the discharge of the primary crusher and at all secondary and tertiary crushers where new dry surfaces and dust are generated by the fracturing of stone. In addition, treatment may also be required at feeders located under surge or reclaim piles if this temporary storage results in sufficient evaporation. Further wetting of the material at screens, conveyor transfer points, conveyor and screen discharges to bins, and conveyor discharges to storage piles may or may not be necessary because, if properly conditioned at application points, the wetted material exhibits a carryover dust control effect that may suppress the dust through a number of material handling operations. The amount of moisture required at each application point is dependent on a number of factors including the wetting agent used, its dilution ratio in water, the type and size of process equipment and the characteristics of the material processed (type, size distribution, feed rate and moisture content).

A typical wet dust suppression system, such as the Chem-Jet System[a] manufactured by the Johnson-March Corporation and illustrated in Figure 4.1, contains a number of basic components and features including: (1) a dust control agent (compound M-R); (2) proportioning equipment;

---

[a] The use of trade names or commercial products does not constitute endorsement or recommendation for use by the Environmental Protection Agency.

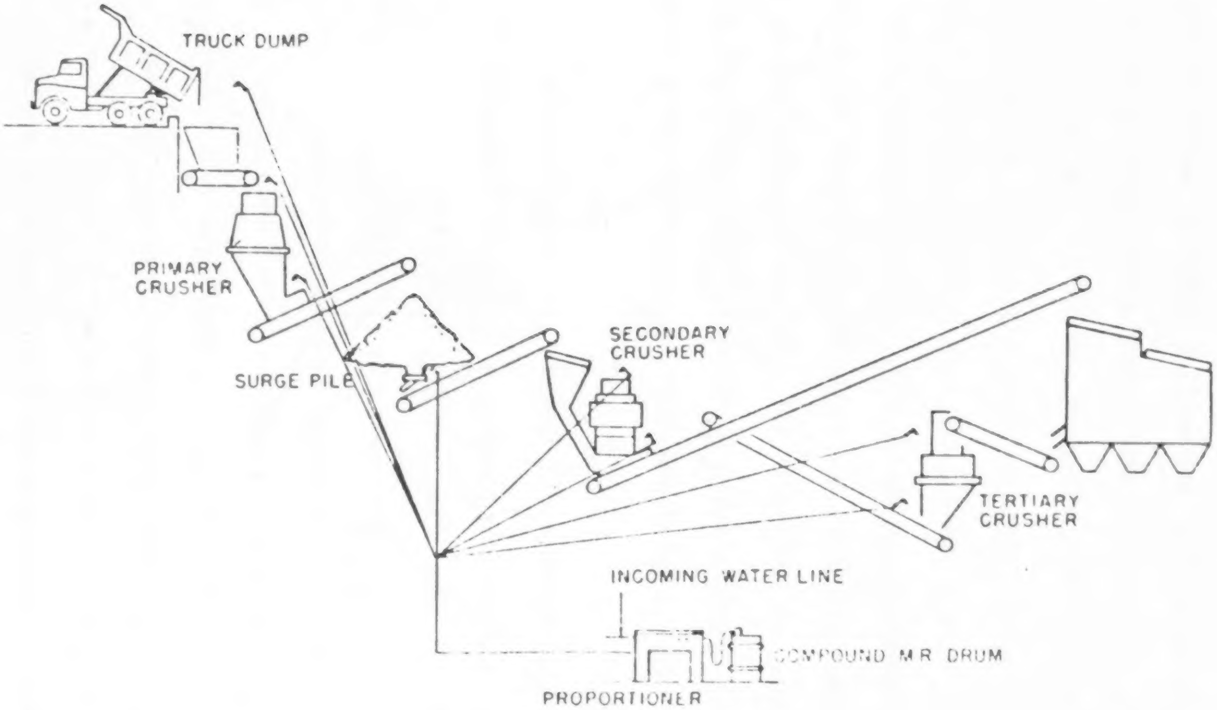

TRUCK DUMP
PRIMARY CRUSHER
SURGE PILE
SECONDARY CRUSHER
TERTIARY CRUSHER
INCOMING WATER LINE
COMPOUND M.R. DRUM
PROPORTIONER

Figure 4.1. Wet dust suppression system.[4]

(3) a distribution system; and (4) control actuators. A proportioner and pump are necessary to proportion the wetting agent and water at the desired ratio and to provide moisture in sufficient quantity and at adequate pressure to meet the demands of the overall system.

Distribution is accomplished by spray headers fitted with pressure spray nozzles. One or more headers are used to apply the dust suppressant mixture at each treatment point at the rate and spray configuration required to effect dust control. A variety of nozzle types may be used including hollow-cone, solid cone or fan nozzles, depending on the spray pattern desired. To prevent nozzle plugging, screen filters are used. Figure 4.2 shows a typical arrangement for the control of dust emissions at a crusher discharge.

Spray actuation and control is important to prevent waste and undesirable muddy conditions, especially when the material flow is intermittent. Spray headers at each application point are normally equipped with an on-off controller which is interlocked with a sensing mechanism so that sprays will be operative only when there is material actually flowing. In addition, systems are sometimes designed to operate under all weather conditions. To provide protection from freezing, exposed pipes are usually traced with heating wire and insulated. When the system is not in use, it should be drained to insure that no water remains in the lines. During periods of prolonged cold weather when temperatures remain below $0^{o}C$, wetted raw materials will freeze into large blocks and adhere to cold surfaces such as hopper walls. Additional labor may be required to prevent such build-ups.

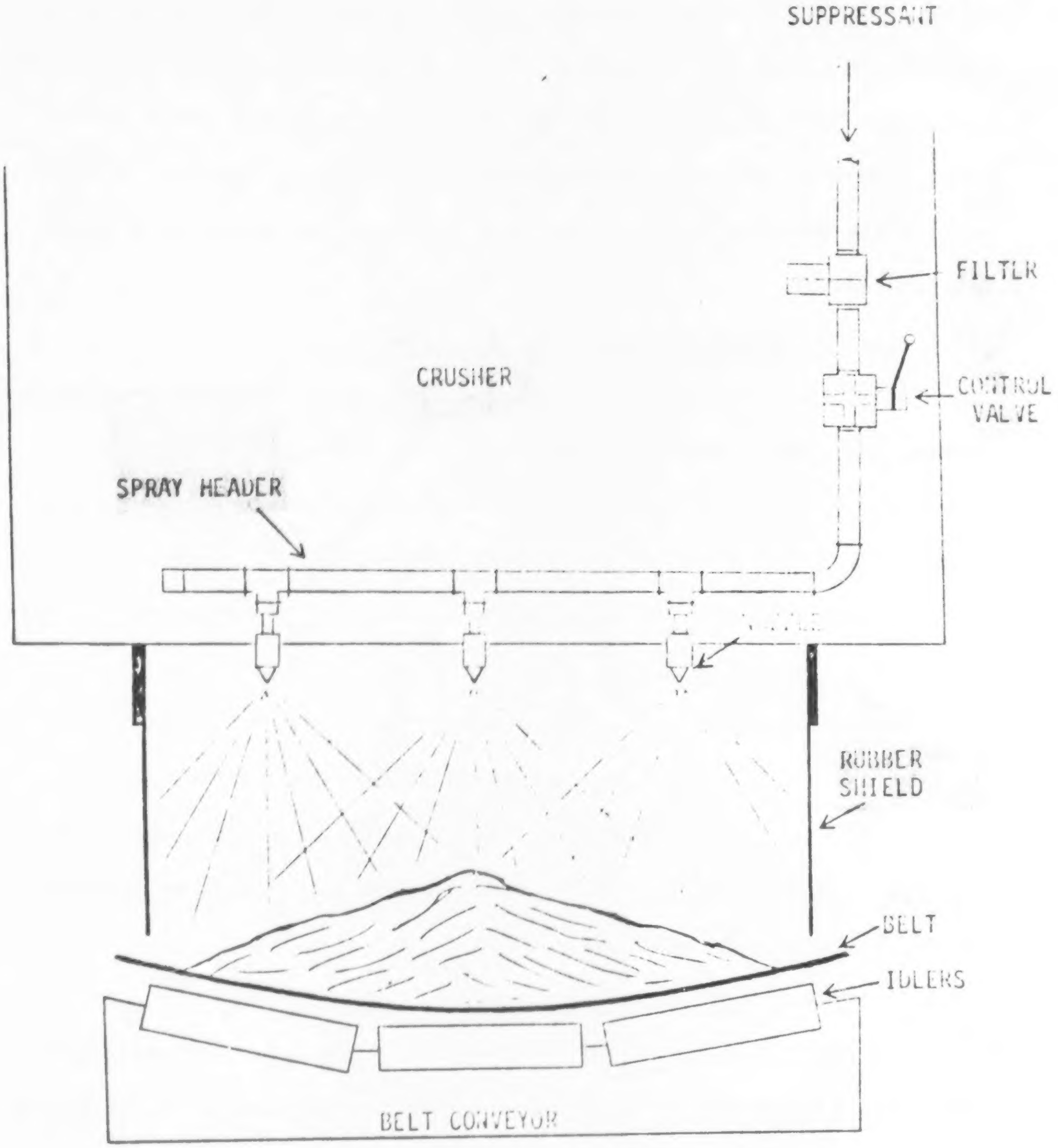

SUPPRESSANT
FILTER
CRUSHER
CONTROL VALVE
SPRAY HEADER
RUBBER SHIELD
BELT
IDLERS
BELT CONVEYOR

Figure 4.2. Dust suppression application at crusher discharge.

At a rock crushing plant with a well designed wet dust suppression system, the Johnson-March Corporation claims that better than 90 percent control efficiency is attainable for the emissions including all process operations from the primary crusher to stockpile and reclaim.[5] Since these emissions are unconstrained and not amenable to testing, no actual particulate emission measurements have been made to verify or dispute this contention.

4.1.2 Dry Collection Systems

Particulate emissions generated at plant process operations (crushers, screens, grinders, conveyor transfer points, fine product loading operations and bagging operations) may be controlled by capturing and exhausting potential emissions to a collection device. Depending on the physical layout of the plant, emission sources may be either manifolded to a single centrally located collector or ducted to a number of individual control units. Collection systems consist of an exhaust system utilizing hoods and enclosures to capture and confine emissions, ducting and fans to convey the captured emissions to a collection device, and the collection device for particulate removal prior to exhausting the air stream to the atmosphere.

4.1.2.1 Exhaust Systems and Ducting

If a collection system is to effectively prevent particulate emissions from being discharged to the atmosphere at the locations where emissions are generated, local exhaust systems including hooding and ducting must be properly designed and balanced. (Balancing refers to adjusting the static pressure balance, which exists at the junction of two branches, to obtain the desired volume in each branch.) Process equipment should be enclosed as completely as practicable, allowing for access for operation, routine maintenance and inspection requirements. For crushing facilities, recommended hood capture velocities range from 61 to 150 meters (200 to 500 feet) per minute.[6,7] In general, a minimum indraft velocity of 61 meters (200 feet) per minute should be maintained through all open hood areas. Proper design of hoods and enclosures will minimize exhaust volumes required and, consequently, power consumption. In addition, proper hooding will minimize the effects of cross drafts (wind) and the effects of induced air (i.e., air placed in motion as a result of machine movement or falling material). A well designed enclosure can be defined as a housing which minimizes open areas between the operation and the hood and contains all dust dispersion action.

Good duct design dictates that adequate conveying velocities be maintained so that the transported dust particles will not settle in the ducts along the way to the collection device. Based on information for crushed stone, conveying velocities recommended for mineral particles range from 1,100 to 1,400 meters/min. (3,500 to 4,500 fpm).[8,9]

Adequate design and construction specifications are available and have been utilized to produce efficient, long-lasting systems. Various guidelines establishing minimum ventilation rates required for the control of crushing plant operations, and upon which the ventilation rates most commonly utilized in the industry are based, are briefly discussed below.

4.1.2.1.1 Crushers and Grinders

Hooding and air volume requirements for the control of crusher and grinder emissions are quite variable depending upon the size and shape of the emission source, the hood's position relative to the points of emission, and the velocity, nature, and quantity of the released particles. The only established criterion is that a minimum indraft velocity of 61 meters per minute (200 fpm) be maintained through all open hood areas. To achieve this, capture velocities in excess of 150 meters per minute (500 fpm) may be necessary to overcome induced air motion, resulting from the material feed and discharge velocities and the mechanically induced velocity (fan action) of a particular equipment type.[10] To achieve effective emission control, ventilation should be applied at both the upper portion, or feed end, of the equipment and at the discharge point. An exception to this would be at primary jaw or gyratory crushers because of the necessity to have ready access to get at and dislodge large rocks which may get stuck in the crusher feed opening. Where access to a device is required for maintenance, removable hood sections may be utilized.

In general, the upper portion of the crusher or grinder should be enclosed as completely as possible, and exhausted according to the criteria established for transfer points (see Section 4.1.2.1.3). The discharge to the transfer belt should also be enclosed as completely as possible. The exhaust rate varies considerably depending on crusher type. For impact crushers or grinders, exhaust volumes may range from 110 to 230 m^3/min. (4,000 to 8,000 cfm).[11] For compression type crushers, an exhaust rate of 46 m^3/min per meter (500 cfm per foot) of discharge opening should be sufficient.[12] The width of the discharge opening will approximate the width of the receiving conveyor. For either impact crushers or compression type crushers, pick-up should be applied downstream of the crusher for a distance of at least 3.5 times the width of the receiving conveyor.[13] A typical hood configuration used to control particulate emissions from a cone crusher is depicted in Figure 4.3

Grinding or milling circuits which employ air conveying systems operate at slightly negative pressure to prevent the escape of air containing the ground rock. Because the system is not airtight, some air is drawn into the system and must be vented. This vent stream can be controlled by discharging it through a control device.

4.1.2.1.2 Screens

A number of exhaust points are usually required to achieve effective control at screening operations. A full coverage hood, as depicted in Figure 4.4, is generally used to control emissions generated at actual screening surfaces. Required exhaust volumes vary with the surface area of the screen and the amount of open area around the periphery of the enclosure. A well-designed enclosure should have a space of no more than 5 to 10 centimeters (2 to 4 inches) around the periphery of the screen. A minimum exhaust rate of 15 m^3/min. per square meter (50 cfm per square foot) of screen area is commonly used with no increase for multiple decks.[14] Additional ventilation air may be

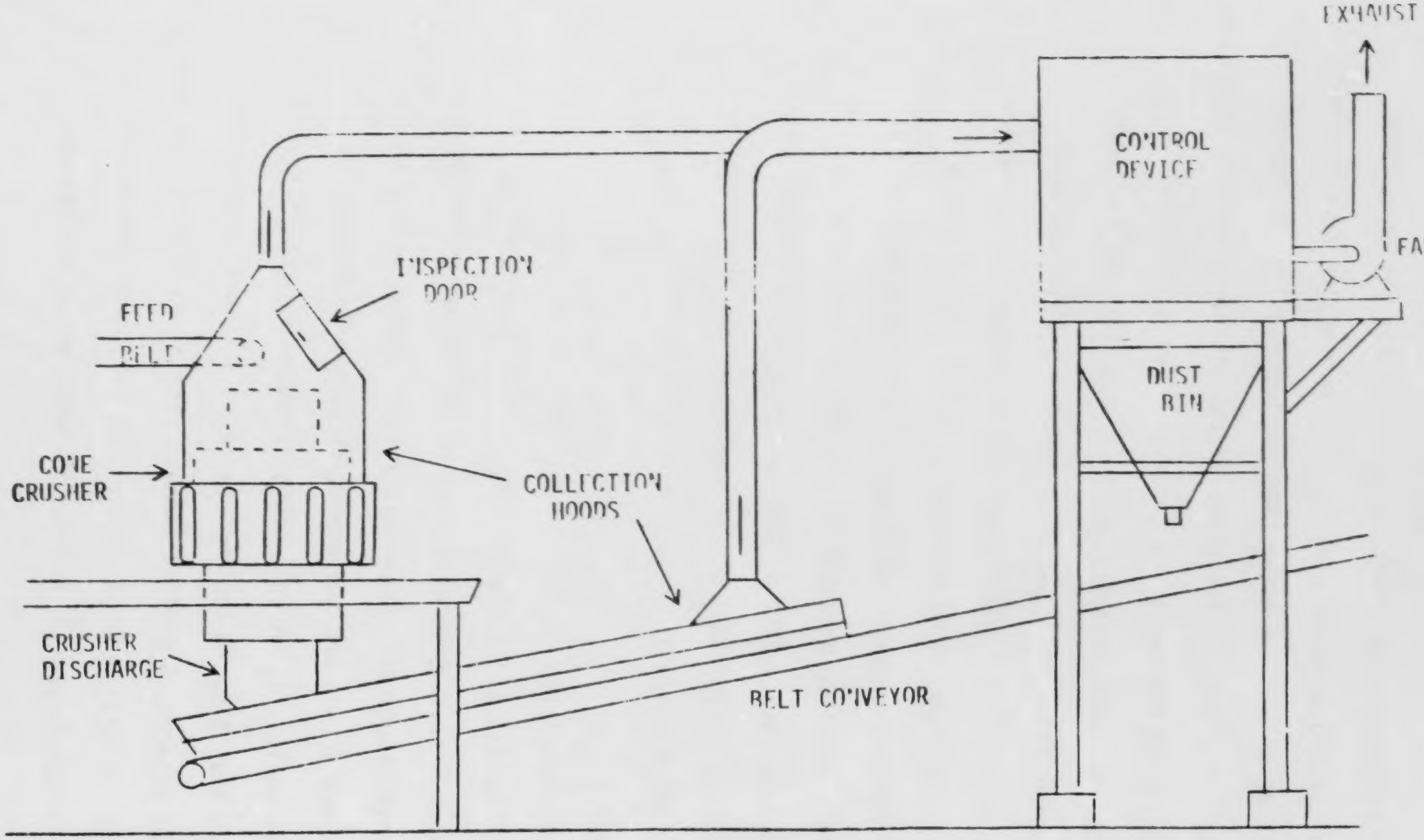

EXHAUST
CONTROL DEVICE
FAN
DUST BIN
INSPECTION DOOR
FEED
BELT
CONE CRUSHER
COLLECTION HOODS
CRUSHER DISCHARGE
BELT CONVEYOR

Figure 4.3. Hood configuration used to control a cone crusher.

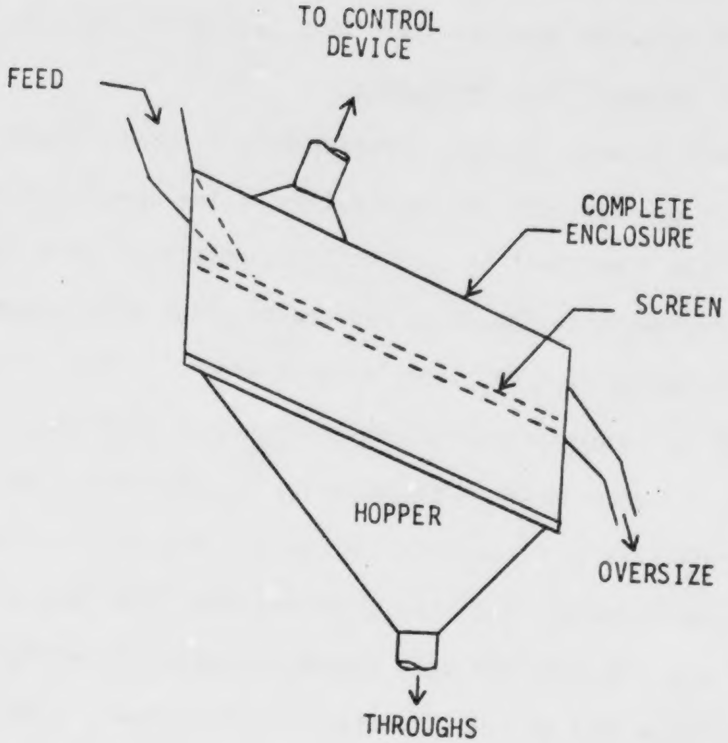

TO CONTROL DEVICE
FEED
COMPLETE ENCLOSURE
SCREEN
HOPPER
OVERSIZE
THROUGHS

Figure 4.4 Hood configuration for vibrating screen.

required at the discharge chute to belt or bin transfer points. If ventilation is needed, these points are treated as regular transfer points and exhausted accordingly. (See Section 4.1.2.1.3).

4.1.2.1.3 Conveyor Transfer Points

At belt to belt conveyor transfer points, hoods should be designed to enclose both the head pulley of the upper belt and the tail pulley of the lower belt as completely as possible. With careful design, the open area should be reduced to about 0.15 square meters per meter (0.5 square feet per foot) of belt width.[15] Factors affecting the air volume to be exhausted include the conveyor belt speed and the free-fall distance to which the material is subjected. Recommended exhaust rates are 33 m^3 per min. per meter (350 cfm per foot) of belt width for belt speeds less than 61 meters/min. (200 fpm) and 150 meters ^{3}/min (500 cfm) for belt speeds exceeding 61 meters/min (200 fpm).[16] For a belt to belt transfer with less than a 0.91 meter (three foot) fall, the enclosure illustrated in Figure 4.5 is commonly used.

For belt to belt transfers with a free-fall distance greater than 0.91 meters (three feet) and for chute-to-belt transfers, an arrangement similar to that depicted in Figure 4.6 is commonly used. The exhaust connection should be made as far downstream as possible to maximize dust fallout and thus minimize needless dust entrainment. For very dusty

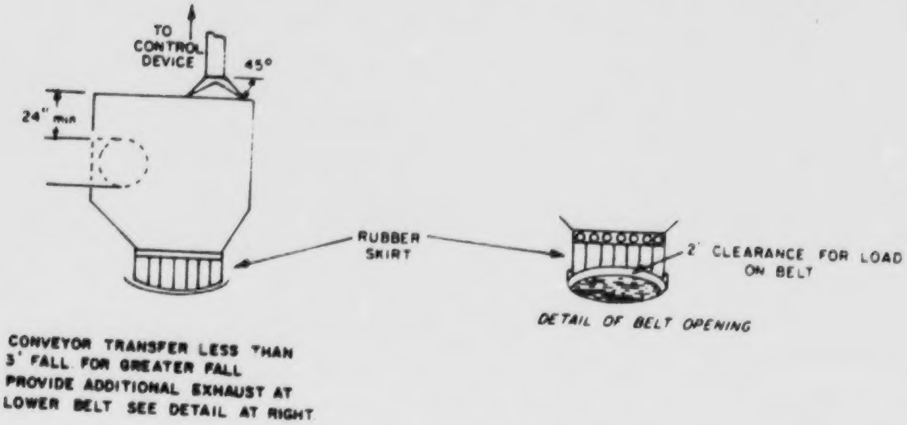

TO CONTROL DEVICE
45°
24" min
RUBBER SKIRT
2" CLEARANCE FOR LOAD ON BELT
DETAIL OF BELT OPENING
CONVEYOR TRANSFER LESS THAN 3' FALL. FOR GREATER FALL PROVIDE ADDITIONAL EXHAUST AT LOWER BELT SEE DETAIL AT RIGHT

Figure 4.5 Hood configuration for conveyor transfer, less than 0.91 meter (3-foot) fall.

material, additional exhaust air may be required at the tail pulley of the receiving belt. Recommended air volumes are 20 m^3/min (700 cfm) for belts 0.91 meters (three feet) wide and less, and 28 m^3/min (1,000 cfm) for belts wider than 0.91 meters (three feet).[17]

Belt or chute-to-bin transfer points differ from the usual transfer operation in that there is no open area downstream of the transfer point. Thus, emissions are emitted only at the loading point. As illustrated

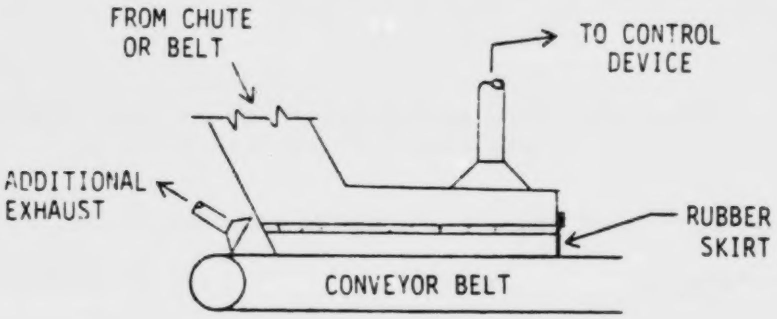

FROM CHUTE OR BELT
TO CONTROL DEVICE
ADDITIONAL EXHAUST
RUBBER SKIRT
CONVEYOR BELT

Figure 4.6 Hood configuration for a chute to belt or conveyor transfer, greater than 0.91 meters (3-foot) fall.

in Figure 4.7, the exhaust connection is normally located at some point remote from the loading point and exhausted at a minimum rate of 61 m^3/min per square meter (200 cfm per square foot) of open area.[18]

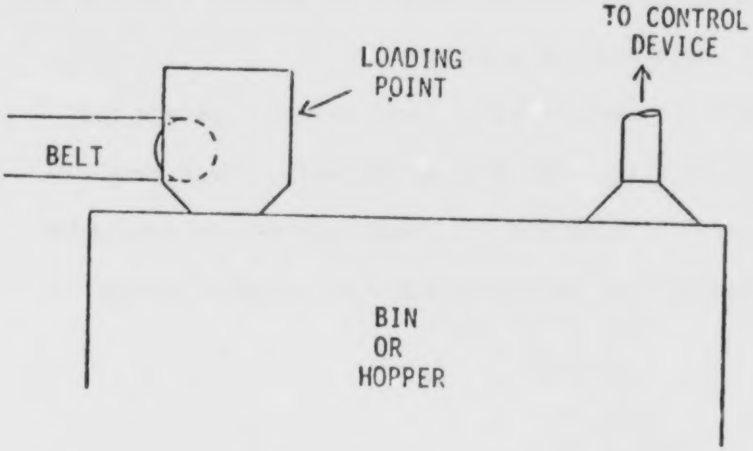


Figure 4.7. Exhaust configuration at bin or hopper.

4.1.2.1.4 Product Loading and Bagging

Particulate emissions from truck and railcar loading of coarse material can be minimized by reducing the open height that the material must fall from the silo or bin to the shipping vehicle. Shrouds, telescoping feed tubes, and windbreaks can further reduce the fugitive emissions from this intermittent source. Particulate emissions from loading of fine material into either trucks or railroad car can be controlled by an exhaust system vented to a fabric filter system. The system is similar to the system described above for controlling bin or hopper transfer points (see Figure 4.7). The material is fed through one of the vehicle's openings and the exhaust connection is normally at another opening. The system should be designed with a minimum amount of open area around the periphery of the feed chute and the exhaust duct.

Bagging operations are controlled by local exhaust systems and vented to a fabric filter system for product recovery. Hood face velocities on the order of 150 meters (500 feet) per minute should be used. An automatic bag filling operation and vent system is shown in Figure 4.8.

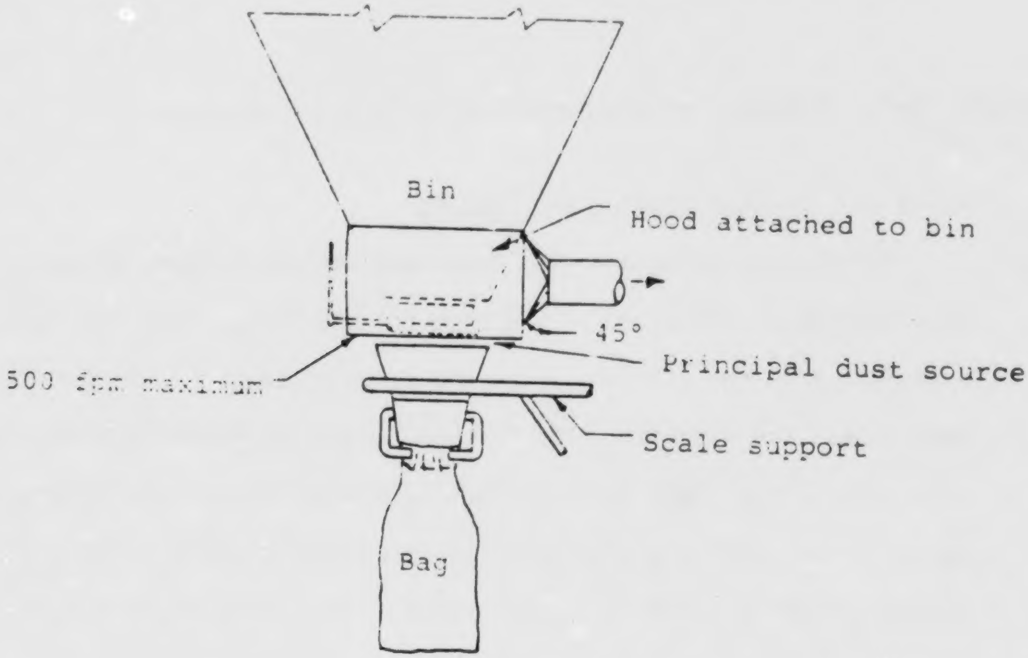

Bin
Hood attached to bin
45°
Principal dust source
500 fpm maximum
Scale support
Bag

Figure 4-8. Bag filling vent system.[19]

4.1.2.2 Collection Devices

The most efficient dust collection device used in the non-metallic mineral industry is the fabric filter or baghouse. For most crushing plant applications, mechanical shaker type collectors which require periodic shutdown for cleaning (after four or five hours of operation) are used. These units are normally equipped with cotton sateen bags and operated at an air-to-cloth ratio of 2 or 3 to 1. A cleaning cycle usually requires no more than two to three minutes of bag shaking and is normally actuated automatically when the exhaust fan is turned off.

For applications where it may be impractical to turn off the collector, fabric filters with continuous cleaning are employed. Although compartmented mechanical shaker types may be used, jet pulse units are predominately used by the industry. These units usually use wool or synthetic felted bags for a filtering media and may be operated at a filtering ratio of as high as 6 or 10 to 1. Regardless of the baghouse type used, jet pulse or shaker, greater than 99 percent efficiency can be attained even on submicron particle sizes.[20] Two baghouses tested by EPA for both inlet and outlet emission levels had collection efficiencies of 99.8 percent.[21,22]

Other collection devices used in the industry include cyclones and low energy scrubbers. Although these collectors may demonstrate efficiencies of 95 to 99 percent for coarse particles (40 microns and larger), their efficiencies are poor, less than 85 percent, for medium and fine particles (20 microns and smaller).[23] Although high energy scrubbers and electrostatic precipitators could conceivably achieve results similar to that of a fabric filter, these methods are not commonly used to control dust emissions in the industry.

Control options for the portable plant segments of the crushed stone, and sand and gravel industries will be discussed in Supplement A.

4.1.2.2.1 Fabric Filters

Fabric filters are high efficiency collection devices used quite extensively throughout the non-metallic minerals processing industry. The greatest variations in the design of baghouses arise from the methods of cleaning the fabric filter and the choice of fabric and size of unit.

The actual extraction of dust is accomplished as shown in Figure 4-9. The airstream enters the baghouse and is pulled up into fabric sleeves that are clustered throughout the apparatus. External draw on the apparatus forces the air to be pulled to the outside of these fabric sleeves which is a "clean area." The dust remains trapped in the weave of the sleeve forming a cake while the cleansed air is exhausted to the atmosphere. The dust is eventually removed from the bag by one of several bag cleaning methods and is either returned to the process or disposed of.

The reverse operation can just as easily be utilized; that is, dirty air travels from the outside to the inside of the bag exiting through the top of the bag, thus leaving the dirt accumulation on the outside of the sleeves.

This accumulation of dust forms a filter cake on the bags which must be removed if there is to be sufficient flow through the system. Care must be taken that the dust is removed and disposed of in such a manner that it does not become reentrained and also that a residual filter cake remains to act as a filtering mechanism in its own right.

Major methods of cleaning are shaking (rapping) and reversing airflow by air jets or pulses. Shaking consists of manually or automatically shaking the bag hangers or rapping the side of the baghouse to shake the dust free into a receiving hopper below.

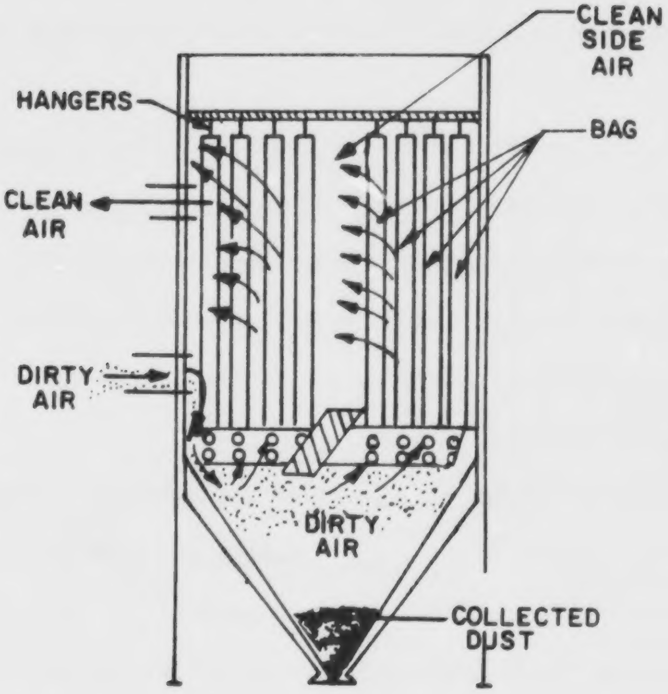

CLEAN SIDE AIR
HANGERS
BAG
CLEAN AIR
DIRTY AIR
DIRTY AIR
COLLECTED DUST

Figure 4.9 Typical baghouse operation.

A less simple method is to use reverse airflow down the tubes at such a rate that there is no net movement of air through the bag. This causes the bag to collapse which results in the filter cake breaking-up and falling off the bag.

A final method is reverse air pulsing where a perforated ring travels up and down each bag or sleeve. Air jets in the ring force the bag to collapse, then reopen, breaking the filter cake apart. These two methods are shown in Figure 4-10.

The frequency of cleaning can be continuous in which a section of baghouse is removed from operation and cleaned before going on to another section. Alternatively, intermittent cleaning consisting of timed cycles of cleaning and operation is used. Sensors can be installed that start the cleaning cycle when some specified pressure drop across the system occurs because of the buildup of the filter cake.

Materials available for bag construction are numerous. They are cotton, Teflon, glass, Orlon, Nylon, Dacron, wool, Dynel, and others. Temperature and other operating parameters must be taken into account in the selection of fabric material, though most industry processes are at ambient conditions. The most popular materials in terms of wear and performance are the synthetic fabrics or cotton sateen.

Several other parameters are considered in the design of baghouses such as frequency of cleaning, cloth resistances to corrosion and ore moisture.

The last major parameter considered is the air-to-cloth ratio or filter ratio defined as the ratio of gas filtered in cubic feet per minute to the area of the filtering media in square feet or $\frac{ft^3/min}{ft^2}$ which reduces to feet (or meters) per minute. Too high a ratio results in possible blinding or

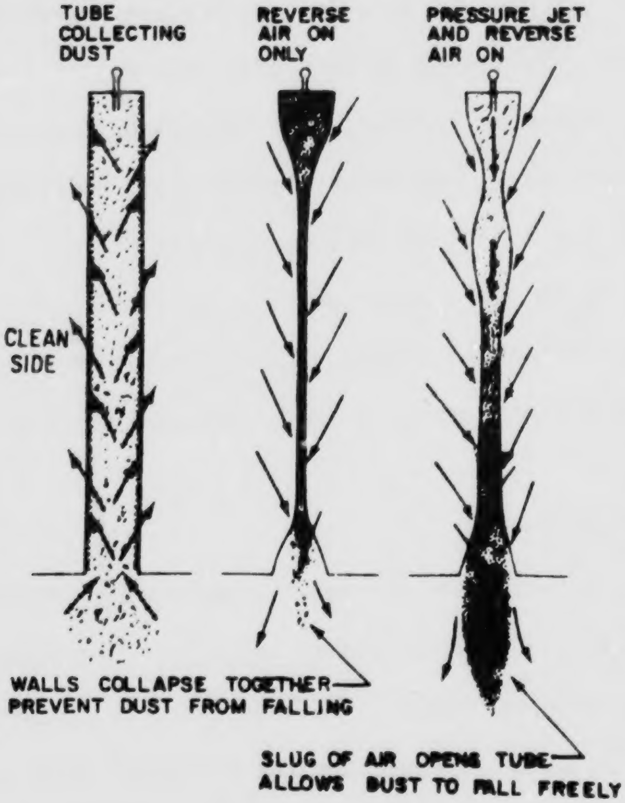

TUBE COLLECTING DUST
REVERSE AIR ON ONLY
PRESSURE JET AND REVERSE AIR ON
CLEAN SIDE
WALLS COLLAPSE TOGETHER PREVENT DUST FROM FALLING
SLUG OF AIR OPENS TUBE ALLOWS DUST TO FALL FREELY

Figure 4.10 Baghouse cleaning methods.[24]

clogging of the bags and a resultant decrease in collection efficiency and increase in bag material wear.

4.1.2.2.2 Wet Capture Devices

The principle of collection in wet capture devices involves contacting dust particles with liquid droplets in some way and then having the wetted and unwetted particles impinge upon a collecting surface where they can be flushed away with water. The method of contacting the dust has many variations depending on the equipment manufacturer. The major types of wet collectors are cyclone, mechanical, mechanical-centrifugal, and Venturi scrubbers.

These devices are more efficient than inertial separators. Wet capture devices can also handle high temperature gases or mist-containing gases. Costs and efficiencies also vary with equipment selection and operating conditions. Efficiencies are higher at lower particle size ranges than with dry cyclones.

4.1.2.2.2.1 Cyclone Scrubbers

As with dry cyclones, wet cyclones impart a centrifugal force to the incoming gas stream causing it to increase in velocity. The principal difference here is that atomized liquids are introduced to contact and carry away dust particles. The dust impinges upon the collector walls with clean air remaining in the central area of the device. Efficiencies in this type of equipment average in the vicinity of 98.2 percent.

4.1.2.2.2.2 Mechanical Scrubbers

These devices have a water spray created by a rotating disc or drum contacting the dust particles. Extreme turbulence is created which insures

Reproduced from
best available copy.

this required contact. Efficiencies are about the same as cyclone wet scrubbers.

Mechanical centrifugal capture devices with water sprays are similar to their dry counterparts with the exception that a water spray is located at the gas inlet so that the particulate matter is moistened before it reaches the blades. The water droplets containing particulate are impinged on the blades while the clean air is exhausted as is depicted in Figure 4-11. In this case, the spray not only keeps the blades wet so that dust will impinge upon them, but it also serves as a medium to carry away particles.

Some types of scrubbers use high pressure-sprays, consuming more energy and water, but have higher efficiencies than other wet capture devices.

Venturi scrubbers rely on an impaction mechanism and extreme turbulence for dust collection. Gas velocities in the throat of the Venturi tube are 4,572 to 6,096 meters (15,000 to 20,000 feet) per minute. It is at this point that low pressure water sprays are placed. The extreme turbulence causes excellent contact of water and particulate. The wetted particles travel through the Venturi tube to a cyclone spray collector. Efficiencies are very high, averaging 99.9 percent.[25] These high efficiencies are also evidenced in the low particle size ranges collected (<1 μm). This design is, indeed, best suited to applications involving removal of 0.5 to 5 micron sizes.

The construction is similar to a Venturi meter with 25° converging and 7° diverging sections. This results in a 4:1 area reduction between the inlet and throat.

4.1.3 Combination Systems

Wet dust suppression and dry collection techniques are often used in combination to control particulate emissions from crushing plant facilities.

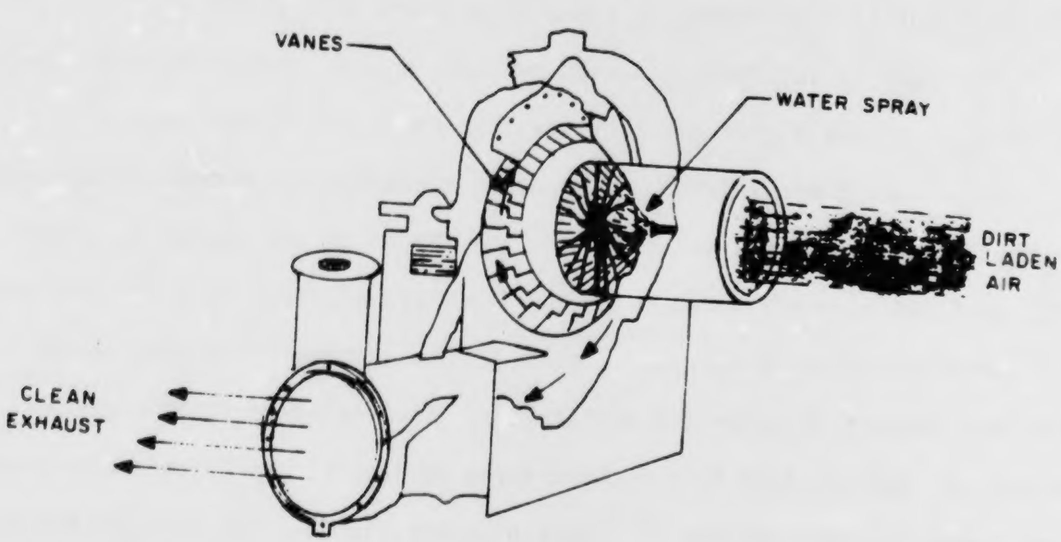

VANES
WATER SPRAY
DIRT LADEN AIR
CLEAN EXHAUST

Figure 4.11 Mechanical, centrifugal scrubber.

As illustrated in Figure 4.12, wet dust suppression techniques are generally used to prevent emissions at the primary crushing stage and at subsequent screens, transfer points and crusher inlets. Dry collection is generally used to control emissions at the discharge of the secondary and tertiary crushers where new dry surfaces and fine particulates are formed. In addition to controlling emissions, dry collection results in the removal of a large portion of the fine particulates generated with the resultant effect of making subsequent dust suppression applications more effective with a minimum of added moisture. Depending on the product specifications, dry collection may also be necessary at the finishing screens.

Dust control for the portable crushing plant segments of the crushed stone, and sand and gravel industries are discussed in Supplement A.

4.2 FACTORS AFFECTING THE PERFORMANCE OF CONTROL METHODS.

4.2.1 Dust Suppression

The effectiveness of wet suppression is dependent on the amount of moisture added to the process flow. There are a number of factors which may affect the performance of a wet dust suppression system. These include the wetting agent used, the method of application, characteristics of the material, and the type and size of the process equipment serviced. The number, type and configuration of spray nozzles at an application point, as well as the speed at which a material stream moves past an application point, may affect both the efficiency and uniformity of wetting. In addition, meteorological factors, such as wind, ambient temperature and humidity, which affect the evaporation rate of added moisture, may

Reproduced from
best available copy.

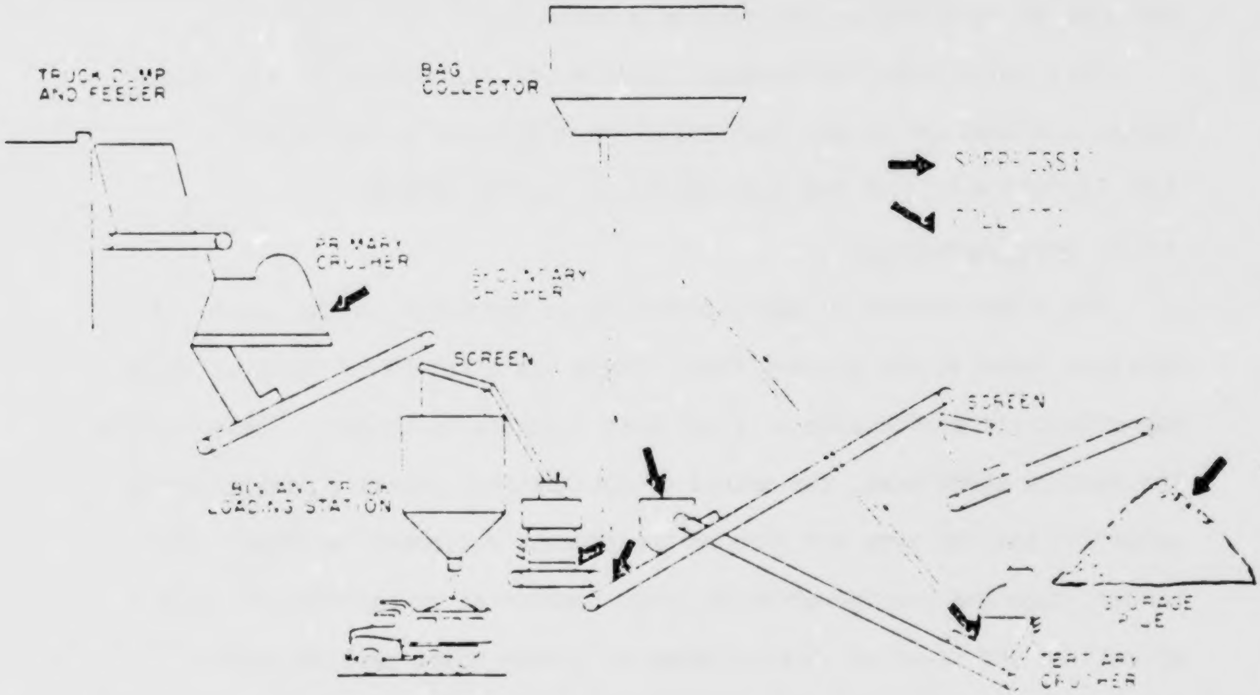

TRUCK DUMP
AND FEEDER
BAG
COLLECTOR
SUPPRESSION
COLLECTION
PRIMARY
CRUSHER
SECONDARY
CRUSHER
SCREEN
BIN AND TRUCK
LOADING STATION
SCREEN
STORAGE
PILE
TERTIARY
CRUSHER

Figure 4.12 Typical combination dust control systems.

also adversely affect the overall performance of a dust suppression system. Where the material processed contains a high percentage of fines, such as the product from a hammermill, dust suppression may be totally inadequate because of the enormous surface areas to be treated.

Dust suppression may offer a viable control alternative to dry collection at process facilities if sufficient moisture is added to the material. Generally, wet dust suppression is only possible with crushing operations (crushers, conveyor transfer points, and screens) because a coarser material is handled and plugging problems will not likely occur. In addition, wet suppression may not be possible in freezing weather or arid regions. Also, some industries (e.g., talc, rock salt) prefer not to handle material with high moisture (even in crushing operations).

4.2.2 Dry Collection

For dry collection systems, factors affecting both capture efficiency and collection efficiency are important. Wind blowing through hood openings can significantly reduce the effectiveness of a local exhaust system. This can be appreciated when one considers that an indraft velocity of 61 meters/min (200 fpm) is equivalent to less than 3.7 km/hr (2.3 mph). Consequently, the process equipment should be completely enclosed or the hood openings minimized.

Installations located in areas of high precipitation have chosen to house process equipment in buildings or structures to increase their operating hours. An added effect of this is to reduce the impact that high winds may have on a local exhaust system which is not properly enclosed. Except for crushed and broken stone plants and sand and gravel plants, much of the processing in the industries investigated in this study occurs in buildings which enclose the equipment.

An exhaust system must be properly maintained and balanced if it is to remain effective. Good practice dictates that systems be periodically inspected and capture and conveying velocities checked against design specifications to assure that the system is indeed functioning properly. The primary causes for systems becoming unbalanced are the presence of leaks resulting from wear due to abrasion or corrosion, and the settling of dust in poorly designed duct runs which effectively reduces the cross sectional area of the duct and increases pressure drop.

4.2.3 Combined Suppression and Collection Systems

The factors affecting the performance of combination systems are the same as those encountered where dust suppression or dry collection systems are used alone.

4.3 PERFORMANCE OF PARTICULATE EMISSION CONTROL TECHNIQUES

4.3.1 Dry Collection Techniques

4.3.1.1 Particulate Emission Data From Non-Metallic Mineral Plants

Particulate emission measurements were conducted by EPA on 16 baghouse collectors used to control emissions generated at crushing, screening, and conveying (transfer points) operations at five crushed stone installations, one kaolin plant, one fuller's earth installation and on one baghouse collector used to control emissions generated at grinding, classifying, and fine product loading operations at a feldspar installation. Table 4.2 briefly summarizes the process operations controlled by each baghouse tested, along with specifications for each baghouse. The results of these measurements are summarized in Figure 4.13. Complete test data summaries, for both mass particulate measurements and visible emission observations, and a description of each process facility tested are contained in Appendix C.

Of the eight plants tested, three processed limestone rock (A, B, and C), two processed traprock (D and E), one processed feldspar (G), one processed kaolin (L), and one processed fuller's earth (M). Four of the five crushed stone plants were commercial crushed stone operations producing a variety of end products including dense-graded road base stone, asphalt aggregates, concrete aggregates and non-specific construction aggregates. In addition, plant B produced about 60 ton/hr of agstone. Facilities A1 through A4 consist of process operations producing raw material for the manufacture of portland cement. Facilities A1 and B1 are both impact crushers used for the primary crushing of run-of-quarry limestone rock. Facility A3 is somewhat unique in that it consists of a single conveyor transfer point at the tail of an overland conveyor. As indicated in Table 4.2, the remaining facilities tested consisted of multiple secondary and tertiary crushing and screening operations, adjunct conveyor transfer points, and grinding operations. These include one primary jaw crusher, three secondary cone crushers, two hammer mills, eight tertiary cone crushers, nineteen screens, thirteen product bins, and over seventeen conveyor transfer points, one pebble mill, two roller mills, one fluid energy mill, one impact mill, one bucket elevator, and a fine product loading system.

TABLE 4.2 BAGHOUSE UNITS TESTED BY EPA

Reproduced from best available copy.

Facility	Rock type processed	Baghouse specifications				Process operations controlled
		Type	Filtering ratio	Capacity		
				scms	scfm	
A1	Limestone	Jet pulse	5.3 to 1	12.5	(26,472)	Primary impact crusher
A2	Limestone	Jet pulse	7 to 1	7.5	(15,811)	Primary screen
A3	Limestone	Jet pulse	7 to 1	1.1	(2,346)	Conveyor transfer point
A4	Limestone	Jet pulse	5.2 to 1	5.0	(10,532)	Secondary cone crusher, screen
B1	Limestone	Shaker	3.1 to 1	2.7	(5,784)	Primary impact crusher
B2	Limestone	Shaker	2.1 to 1	8.6	(18,197)	Scalping screen, secondary cone crusher, two finishing screens, hammer mill, five storage bins, six conveyor transfer points
C1	Limestone	Shaker	2.3 to 1	3.5	(7,473)	Primary jaw crusher, scalping screen, hammer mill
C2	Limestone	Shaker	2.0 to 1	3.1	(6,543)	Two finishing screens, two conveyor transfer points
D1	Traprock	Shaker	2.8 to 1	15.0	(31,863)	One scalping and two sizing screens, secondary cone crusher, two tertiary cone crushers, several conveyor transfer point
D2	Traprock	Shaker	2.8 to 1	12.3	(25,960)	Finishing screen, several conveyor transfer points
E1	Traprock	Jet pulse	5.2 to 1	7.0	(14,748)	Two sizing screens, four tertiary cone crushers; several conveyor transfer points
E2	Traprock	Jet Pulse	7.5 to 1	10.0	(21,122)	Five finishing screens, eight storage bins
M1	Fuller's earth	Reverse air	6.0 to 1	0.9	(1,800)	Raymond and fluid energy mills, conveyor transfer points, vibrating screens
M2	Fuller's earth	Reverse air	5.2 to 1	1.6	(3,300)	
G1	Feldspar	Reverse air	3.0 to 1	1.9	(3,960)	Pebble mill, bucket elevator, two conveyor transfer points, fine product loading
L1	Kaolin	Unknown	Unknown	6.6	(14,040)	Raymond impact mill
L2	Kaolin	Unknown	Unknown	3.3	(6,960)	Roller mill

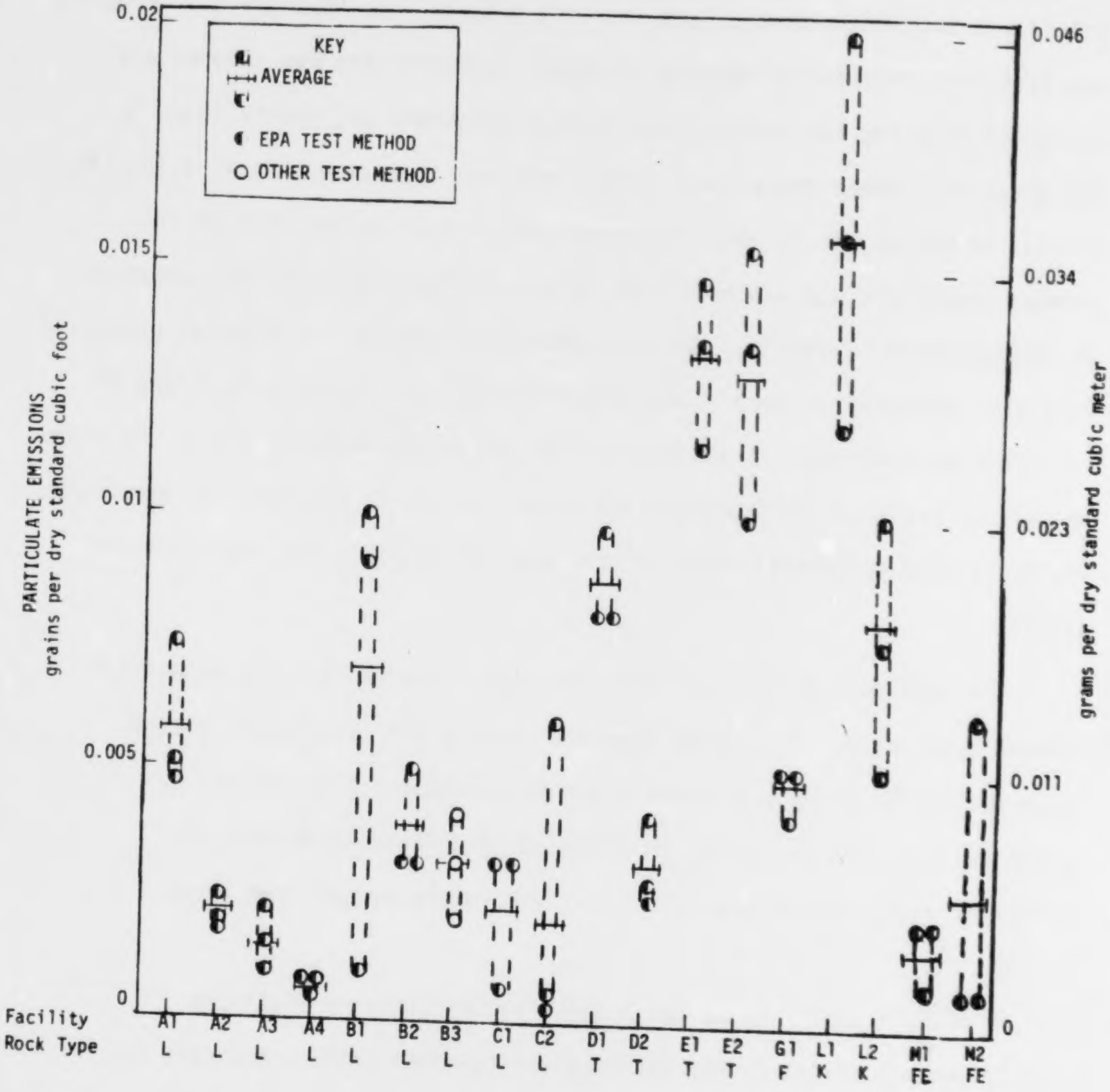


Figure 4.13 Particulate emissions from non-metallic minerals processing operations.

A minimum of three test runs, using EPA Method 5 or 17, were conducted at each process operation tested. (For this industry, both EPA Method 5 and 17 are acceptable particulate sampling methods, see Appendix D.) Sampling was performed only during periods of normal operation and was stopped and restarted to allow for intermittent process shutdowns and upsets (feed to the process). Where the process weight rate was undeterminable at a specific process operation, as in most instances, the process weight through the primary crushing stage was monitored to assure that the plant was operating at or near normal capacity. Moisture determinations on the material processed were also performed at each plant tested (except for plants A, G, L and M) to permit an assessment of whether control was effected primarily by the dust collection system or by excessive moisture inherent in the material processed. The tests were considered valid if the material moisture was less than two percent.

The baghouses tested included jet pulse, reverse air, and mechanical shaker type units. The shaker type and reverse air type fabric filters used cotton sateen bags and were operated at about 2:1 to 3:1 air-to-cloth ratios. The jet pulse units tested were fitted with wool or synthetic fiber felted bags. Air-to-cloth ratios ranged from about 5:1 to 7.5:1.

A study[26] performed by the Industrial Gas Cleaning Institute (IGCI) under contract to EPA reported air-to-cloth ratios necessary to achieve 0.05 g/dscm (0.02 gr/dscf) for the various industry segments based upon the experience of their member companies. Table 4.3 presents this information. These ratios are based upon the following premises:

1. Air from a dry crushing or grinding operation at or near ambient temperature.
2. An inlet particulate content of 10 grains per standard cubic foot for a volume of air equivalent to that required for a face velocity of 200 ft/min at crusher openings.
3. A particle size average of 20 microns and a range from 0.5 to 100 microns.
4. No insulation or heating required.

The IGCI report states that the segments considered the most troublesome are those with the lowest air-to-cloth ratio. The lower ratios employed for some segments are premised upon such particulate properties as a high abrasiveness or a tendency to "blind" the filtering medium. The study further states that no differentiation in the air-to-cloth ratio is required for the source of emission be it crushing or grinding operation. An exception would be a micromill source emitting an average particle size smaller than that cited (i.e. 20 microns). For such a source, a lower air-to-cloth ratio would be needed than that indicated in Table 4.3.

The industry segment with the lowest air-to-cloth ratio listed in Table 4.3 is feldspar. EPA conducted tests for particulate emissions at a feldspar plant on a baghouse controlling emissions from a pebble mill system. The results of these tests indicate particulate emissions below 0.023 g/dscm (0.01 gr/dscf). The baghouse had a design air-to-cloth ratio of 3.03.

Table 4.3. AIR-TO-CLOTH RATIOS FOR FABRIC FILTERS USED FOR EXHAUST EMISSION CONTROL

Industrial segment	Air-to-cloth ratio[a] acfm/ft^2
Sand and gravel	7.
Clay	6.
Gypsum	6.
Lightweight aggregate	7.5
Perlite	
Vermiculite	
Pumice	4.5
Feldspar	4.
Borate	5.
Talc and Soapstone	5.
Barite	5.
Diatomite	6.
Rock Salt	4.5
Fluorspar	6.
Mica	6.
Kyanite	4.5
Sodium Compounds	6.
Gilsonite	N.R.[b]
Crushed and broken stone	7.

[a] Ratio is based on operating surface required to obtain a particulate concentration of 0.02 grain per standard cubic foot in the outlet stream from the filter. In all cases, the filter is a pulse-jet type operating at 6 in. W.G. differential pressure. The filtering medium is felted polypropylene or polyester.

[b] No recommendation for this segment.

In addition, the IGCI report listed test results (using EPA sampling Method 5) for two fluid energy mills processing clay (fuller's earth). In both cases, the particulate emissions were controlled by a fabric filter and were below 0.023 g/dscm (0.01 gr/dscf). The average particle size of the inlet stream was reportedly below 10 microns in both cases. EPA conducted tests for particulate emissions from a roller mill and a fluid energy mill, both used to grind fuller's earth clay. In both cases particulate emissions were controlled by baghouses. Emissions from the baghouse controlling the roller mill were less than 0.005 g/dscm (0.002 gr/dscf) and those from the fluid energy mill baghouse were less than 0.015 g/dscm (0.006 gr/dscf).

Tests were also conducted at two talc plants and a gypsum plant on baghouses controlling particulate emissions from various process sources. Emissions from these baghouses were greater than 0.05 g/dscm (0.02 gr/dscf). The higher emission levels are suspected to have been caused by the presence of torn bags since there were excessive visible emissions either continuously or frequently. Tests conducted at a kaolin plant on an impact mill and a roller mill resulted in measured emission rates of 0.037 and 0.016 g/dscm (0.016 and 0.007 gr/dscf) respectively, for the two process operations.

As previously indicated, test results are presented on only three of the 18 industries being covered. These are crushed stone (limestone and trapock), feldspar, and clay (fuller's earth, kaolin). The crushed stone data are on crushing operations and associated process equipment. The data for feldspar, kaolin, and fuller's earth clay are for grinding systems. All the facilities tested are controlled by fabric filter collectors. Since the performance of fabric filter collectors is relatively unaffected by the size distribution of particulate, the emission levels from properly designed baghouses should be nearly the same over the wide variety of non-metallic minerals being covered.[27,28] Furthermore, the IGCI report stated that there is no difference in performance of a baghouse whether it is installed on a crushing or grinding operation for a particular industry. The differences in design (air-to-cloth-ratio) of a baghouse for the various industries are premised upon such particulate properties as high abrasiveness or a tendency to "blind the filtering medium." The IGCI report also states that the worst situation would be a source emitting an average particle size smaller than 20 microns. The clay grinding mills (fluid energy mill, see Section 3.2.2.3.4) tested are the type of grinders generally used when an ultrafine product is required. Therefore, the data presented on the clay grinding mills, which have an average particle size of 6 microns or less, would represent the levels achievable under worst conditions.

As discussed earlier, the average emission concentration for the different process facilities using properly operated baghouses at the various non-metallic industries shown in Figure 4-13 was 0.011 g/dscm (0.005 gr/dscf). The average outlet concentration at any of these facilities never reached 0.046 g/dscm (0.02 gr/dscf). In conclusion, it is felt that the data presented here are representative of the levels that can be achieved by a properly designed baghouse in each of the 18 industries.

4.3.1.2 Particulate Emission Data From Metallic Mineral Plants[29]

In order to broaden the range of conditions considered for the performance of the control equipment, test data for metallic mineral processing facilities are also included in the data base discussed in this chapter. Data from the metallic mineral industries may be appropriately transferred to the non-metallic mineral industries for several reasons. Much of the process equipment of interest in this document is similar in the metallic and non-metallic processing industries. Because the ores from which metallic elements are extracted are primarly non-metallic in character, the emissions from metallic mineral processing operations are primarily non-metallic mineral constituents. Furthermore, the similarity of emissions from metallic and non-metallic processes in key parameters such as particle size distribution and mass loading provide additional evidence of similarity between the two industries. These measurements were routinely made during the testing of both metallic and non-metallic processing facilities and form the basis for extrapolating control efficiency from one industry, whether metallic or non-metallic, to another.

Particulate emissions were measured by EPA for 8 baghouses used to control emissions from crushing, screening, drying, and conveying operations at 5 metallic mineral processing sites. Table 4-4 presents a summary of baghouse types and filter ratios (air-to-cloth) of the baghouses tested by EPA for which information was available. Figure 4-14 presents emission levels after baghouse control.

Plant V processes copper ore mined from low grade deposits (0.5 percent copper) into concentrate. This plant used a baghouse (V1) to control emissions from a railcar loading operation that handled copper ore concentrate. Use of baghouses under these conditions is fairly common because the valuable product captured by the baghouse can be returned directly to the operation. A weighted average of the truck loadout hood and the conveyor exhaust gave a calculated combined inlet concentration of 0.71 g/dscm (0.31 gr/dscf). The baghouse outlet concentration averaged 0.03 g/dscm (0.013 gr/dscf) as shown in Figure 4-14. Twenty percent of the inlet particles at both truck loadout hood and conveyor belt exhaust were smaller than 4 microns.

TABLE 4-4. BAGHOUSE UNITS TESTED BY EPA
(METALLIC MINERAL PROCESSING)

Baghouse	Baghouse type	Filtering ratio	Process operations controlled
V1	NA	NA	Truck/railcar loadout and associated conveyor transfer point
W1	Pulse jet	7.4 to 1	Secondary and tertiary crushers and associated screens
W2	Pulse jet	7.1 to 1	Fine crushers to concentrator conveyor
W3	Pulse jet	6.5 to 1	Ore car dump
X1	Shaker	2.9 to 1	Primary crusher complex including two grizzly screens, primary crusher hood, and ore bins
X2	Shaker	2.9 to 1	Two truck dump stations
Y1	Pulse jet	8 to 1	Ore storage bins
Z1	Pulse jet	9.1 to 1	Primary, secondary and tertiary crushing, conveyor transfer point, and ore storage relclaim area

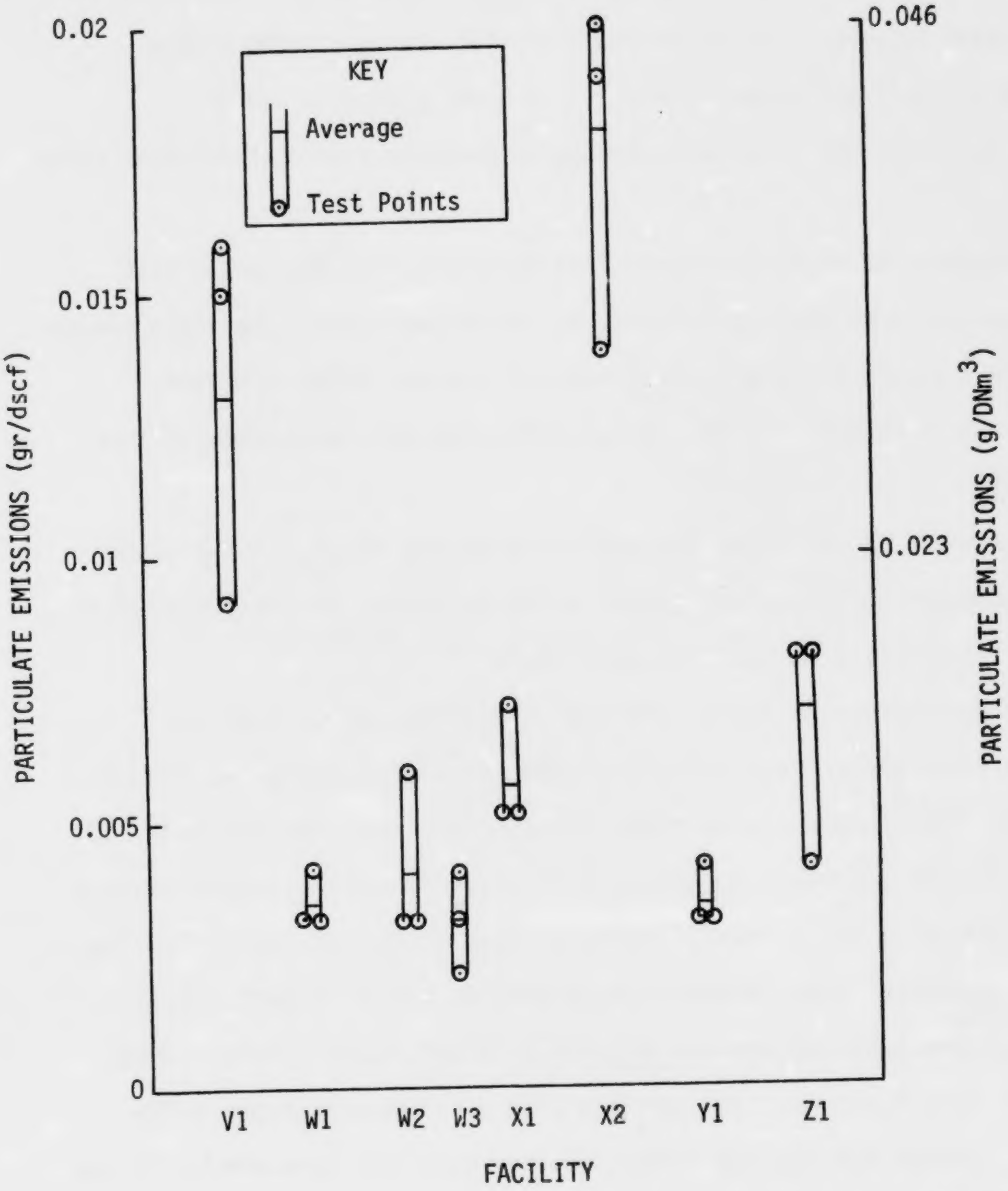


Figure 4-14. Particulate emissions from baghouses at metallic mineral processing operations.

Plant W processes iron ore mined from an open pit operation. Baghouse W1 controlled emissions from a secondary and tertiary crushing operation and associated screens. The outlet concentration averaged 0.008 g/dscm (0.003 gr/dscf) and ranged from 0.007 to 0.009 g/dscm (0.003 to 0.004 gr/dscf). No inlet measurements or particle size distributions were taken.

Baghouse W2 at Plant W controlled emissions from the system that conveyed ore from the fine crushers to the concentrator. The inlet concentration averaged 3.0 g/dscm (1.31 gr/dscf) and the outlet averaged 0.009 g/dscm (0.004 gr/dscf). No particle size data were taken at this facility.

Baghouse W3 controlled emissions from an ore car dump. The outlet concentration averaged 0.007 g/dscm (0.003 gr/dscf). No inlet measurements or particle size distribtutions were taken.

Plant X processes copper ore from an open pit mine. Baghouse X1 controls emissions from a primary crusher complex including two grizzly screens, the primary crusher hood, and ore bins. The combined inlet duct concentration averaged 5.43 g/dscm (2.37 gr/dscf) and the outlet averaged 0.013 g/dscm (0.006 gr/dscf). Particle sizes of the combined inlet flow were relatively large. Ninety-five percent of the inlet particles were greater than 8 microns whereas 25 percent of the outlet particles were greater than 8 microns. The particle size distributions taken at the grizzly screen duct and the primary crusher hood duct were similar to the combined inlet duct.

Baghouse X2 controlled emissions from two truck dump stations from which ore was fed to the primary crusher. The combined inlet concentrations averaged 0.304 g/dscm (0.133 gr/dscf) while the outlet averaged 0.041 g/dscm (0.018 gr/dscf). Fifty percent of the inlet particles were less than 4 microns while 20 percent of the outlet particle size distribution was below that level.

Plant Y processed imported bauxite into alumina. One pulse jet baghouse controlling emissions from an ore bin complex was tested. The control equipment configuration prevented sampling of the inlet duct. The outlet from these ore bins averaged 0.007 g/dscm (0.003 gr/dscf) and ranged from 0.007 to 0.009 g/dscm (0.003 to 0.004 gr/dscf).

Plant Z processed gold ore from an underground mining operation. The baghouse at the milling operation controlled emissions from the primary, secondary, and tertiary curshers, an ore storage inlet, and associated conveyor transfer operations. This baghouse had a design air-to-cloth ratio of 9.1:1 and operated with a pulse jet cleaning system.

During the testing of this baghouse, ore from 1500-1800 meters (5000-6000 feet) underground was being processed. This ore was characterized by high levels of unbound water (4 to 5 percent) and warm temperatures (25 to 30°C (80° to 90°F)) due to the depths from which it was extracted. Because milling took place at the surface where the winter temperature was 0 to 7°C (30 to 45°F) condensation of moisture in the inlet ducts of the baghouse was very evident. The high moisture emissions combined with the relatively high air-to-cloth ratio caused blinding of the fabric filters rendering the pulse jet cleaning system ineffective. As a consequence, the pressure drop at the baghouse rose beyond design levels.

To circumvent this problem, the filter bags were cleaned by manually air-lancing them before each test. The pressure drop at the baghouse was monitored closely during the tests.

The duct configuration of the baghouse prevented measurement of the combined inlet concentration. The weighted average of the crusher inlet, the conveyor transfer inlet, and the ore storage reclaim inlet resulted in a concentration of 0.39 g/dscm (0.17 gr/dscf). The outlet concentration averaged 0.015 g/dscm (0.007 gr/dscf). The particle size distribution at all three inlet ducts were similar. Thirty to forty percent of the particles were less than 10 microns in diameter.

4.3.1.3 Visible Emissions Data

Visible emission observations were also made during the emission tests described above. The opacity of the exhaust from each of the baghouses was observed in accordance with EPA Method 9 procedures (Appendix A, 40 CFR Part 60). Method 9 measures emissions in terms of percent opacity ranging from 0 percent, representing no interference with transmission of light, to 100 percent, representing complete interference with light transmission. Readings are taken at 15 second intervals and averaged over 6-minute periods.

As shown in Table 4-5, 21 of 24 baghouses showed zero emissions during all observation periods. The highest 6-minute average recorded at Plant B was 1 percent opacity. The highest 6-minute average for Baghouse 1 at Plant X was 1 percent opacity and for Baghouse 2, the highest reading was 6 percent opacity. Plant L, a kaolin plant, exhibited continuous visible emissions of less than 5 percent opacity. This was considered to

TABLE 4-5. OPACITY MEASUREMENTS FROM BAGHOUSE EXHAUST STACKS

Baghouse	Processes controlled	Mean opacity (percent)	Highest 6 minute average opacity (percent)	Lowest 6 minute average opacity (percent)
A1	Primary crusher	0	0	0
A2	Primary crusher screen	0	0	0
A3	Primary crusher transfer point	0	0	0
A4	Secondary crusher and screen	0	0	0
B1	Primary crusher	0	1	0
B2	Secondary crusher complex	0	1	0
C1	Primary crusher and hammer mill	0	0	0
C2	Screens and conveyor transfer points	0	0	0
D1	Secondary and tertiary crushers and screens	0	0	0
D2	Screens and transfer points	0	0	0
E1	Tertiary crushers and screens	0	0	0
E2	Screens and conveyor transfer points	0	0	0
G1	Pebble mill, bucket elevator, transfer points, and product loadout	0	0	0
L1	Impact mill	0	0	0
L2	Roller mill	0	0	0
M1	Roller mill	0	0	0
M2	Fluid energy mill	0	0	0
V1	Product loading including truck dump hopper, and railcar loading	0	0	0
W1	Secondary and tertiary crushing operations and associated screens	0	0	0
W2	Conveyor transfer points	0	0	0
W3	Ore care dump	0	0	0
X1	Primary crusher complex including grizzly screens, primary crusher hood, and ore bins	0	1	0
X2	Truck dump hopper	1	6	0
Y1	Ore storage bin	0	0	0
Z1	Primary, secondary, and tertiary crushers, ore storage, and conveyor transfer points	0	0	0

be steam, since only the first of three tests (which was conducted in the morning) had visible emissions. As the temperature of the ambient air rose, the visible emissions dissipated.

Observations for visible emissions were also made at hoods and enclosures to record the opacity of emissions escaping capture. The results of these measurements are summarized in Table 4.6. Complete data summaries are contained in Appendix C. In most instances, essentially no visible emissions were observed at adequately hooded or enclosed process facilities.

Of the 13 crushers for which visible emission measurements are reported, 10 were cone crushers handling either limestone, traprock, feldspar, or talc. The other three crushers were an impact crusher handling limestone and jaw crushers handling feldspar and talc. Visible emissions observed from crushers were less than 10 percent opacity.

Visible emissions were observed at six grinding mills. All the mills exhibited visible emissions of less than five percent. Visible emissions tests were conducted at the truck loading and railcar bulk loading operations of a kaolin plant. Visible emissions were less than 5 percent during both loading operations. The primary source of emissions was the topping of each compartment and the subsequent repositioning of the feed hose in the next compartment.

Opacity measurements are also reported for eight screens, seven conveyor transfer points, one bucket elevator, one product bin, and two baggers. Visible emissions were less than 10 percent opacity from these process facilities.

TABLE 4-6. SUMMARY OF VISIBLE EMISSIONS MEASUREMENTS FROM FUGITIVE SOURCES AT NON-METALLIC MINERALS PLANTS

Plant	Rock type processed	Date of test	Process facility	Mean opacity (percent)	Highest 6-minute average opacity (percent)	Lowest 6-minute average opacity (percent)
B	Crushed limestone	07/01/75	Scalping screen	1	4	0
			Surge bin	0	1	0
			Secondary cone crusher No. 1	0	2	0
			Secondary cone crusher No. 2	0	0	0
			Secondary cone crusher No. 3	0	0	0
			Hammer mill	0	0	0
			3-deck finishing screen (L)	0	1	0
			3-deck finishing screen (R)	0	0	0
		06/30/75	Two 3-deck finishing screens	5	8	2
D	Crushed stone	07/08/75	No. 1 tertiary gyrasphere cone crusher	0	0	0
			No. 2 tertiary gyrasphere cone crusher	0	0	0
			Secondary standard cone crusher	0	0	0
			Scalping screen	0	0	0
			Secondary (2-deck) sizing screen	0	0	0
			Secondary (3-deck) sizing screen	0	0	0

(continued)

TABLE 4-6. (continued)

Plant	Rock type processed	Date of test	Process facility	Mean opacity (percent)	Highest 6-minute average opacity (percent)	Lowest 6-minute average opacity (percent)
F	Traprock	08/26/76	Two tertiary crushers	0	0	0
			Four processing screens	0	0	0
			Conveyor transfer points	0	0	0
G	Feldspar	09/27/76	Ball mill (feed end)	0	0	0
			Ball mill (discharge end)	0	0	0
			Indoor transfer point No. 1	0	0	0
			Indoor transfer point No. 2	0	0	0
			Indoor bucket elevator	0	0	0
			Truck loading	0	0	0
			Rail car loading	1	2	0
H	Gypsum	10/27/76	Hammer mill	0	1	0
I	Mica	09/30/76	Bagging operation	0	0	0
J	Talc	10/21/76	Vertical mill	0	0	0
			Primary crusher	2	4	0
			Secondary crusher	0	1	0
			Bagger	1	9	0
			Pebble mill	0	2	0

4.3.2 Wet Dust Suppression Techniques

Due to the unconfined nature of emissions from facilities controlled by wet suppression technique, the quantitative measurement of mass particulate emissions is not possible. Thus, no mass emission data are available which permit a quantitative comparison of the control capabilities of wet dust suppression versus dry collection techniques. Visible emission observations were conducted at six crushed stone, and sand and gravel facilities (facilities F, P, Q, R, S, T) using wet dust suppression techniques to control particulate emissions generated at plant process facilities. Emissions generated by 13 crushers, 14 screens, 7 transfer points, 1 impact mill and 1 storage bin were visually measured by EPA Methods 9. Facilities R and T are portable crushing facilities. Facilities P, Q, R, and T process crushed limestone, while facility F processes crushed traprock, and facility S produces crushed granite.

The results of the tests for non-crushing sources (e.g., screens, transfer points, and storage bins) are summarized in Table 4.7. These results indicate that visible emissions were 10 percent opacity or less. The results of the tests for crushing sources from the best controlled stationary (facility S) and portable (facilities R and T) plants are summarized in Figures 4.15 to 4.19. The data are reported in 6-minute averaging of Method 9 data. For each testing set (approximately 1 hour), the results of the two observers simultaneously measuring visible emissions, are indicated by a solid and a dashed line. In spite of the fact that facility R is designated a well controlled portable crushing plant, the secondary crusher exceeded 15 percent opacity several times, according to one of the observers. This is attributed to the fact that during the test, there

TABLE 4-7. SUMMARY OF VISIBLE EMISSIONS MEASUREMENTS FROM FUGITIVE NONCRUSHING SOURCES CONTROLLED BY WET SUPPRESSION (ACCORDING TO EPA METHOD 9)

Plant	Rock type processed	Date of test	Process facility	Mean opacity (percent)	Highest 6-minute average opacity (percent)[a]	Lowest 6-minute average opacity (percent)
P	Crushed limestone (S)[b]	10/02/79	Secondary screen	0	0	0
			Transfer point	0	3	0
Q	Crushed limestones (S)	10/10/79	Three process screens	2	10	0
R	Crushed sand and gravel (P)[c]	10/15/79	Three process screens	1	5	0
			Two transfer points	1	5	0
S	Crushed granite (S)	10/23/79	Two process screens	0	4	0
			Two transfer points	0	0	0
T	Crushed limestone (P)	10/29/79	Process screen	0	0	0
			Transfer point	0	0	0
			Storage bin	0	2	0
F	Crushed traprock (S)	08/26/76	Four process screens	0	0	0
			Transfer point	0	0	0

[a] Data from observer with highest readings.

[b] (S) = Stationary plant.

[c] (P) = Portable plant.

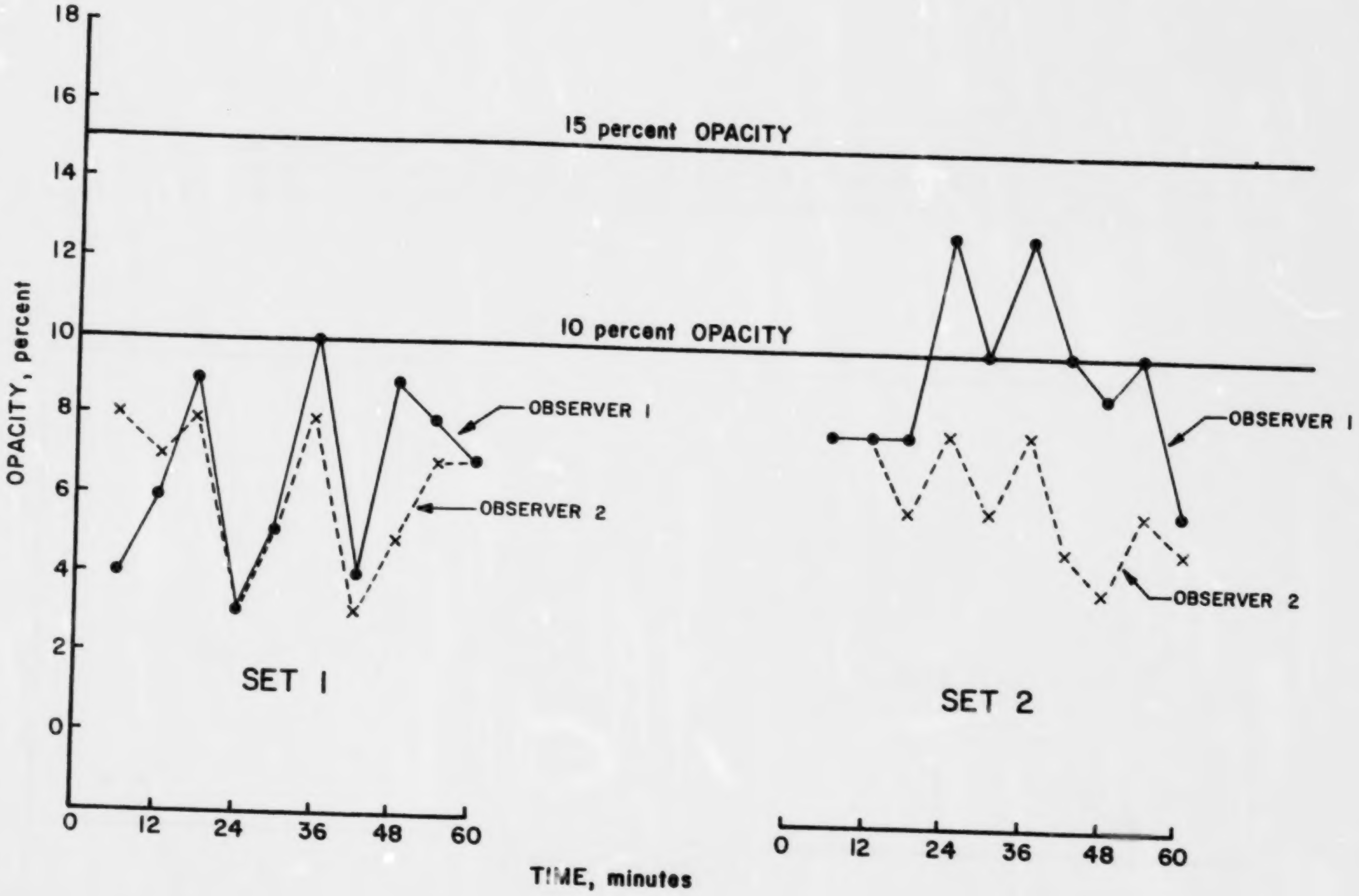


Figure 4-15. Summary of visible emission measurements from best controlled fugitive primary crushing sources (portable-Facility T) by means of wet suppression (according to EPA Method 9).

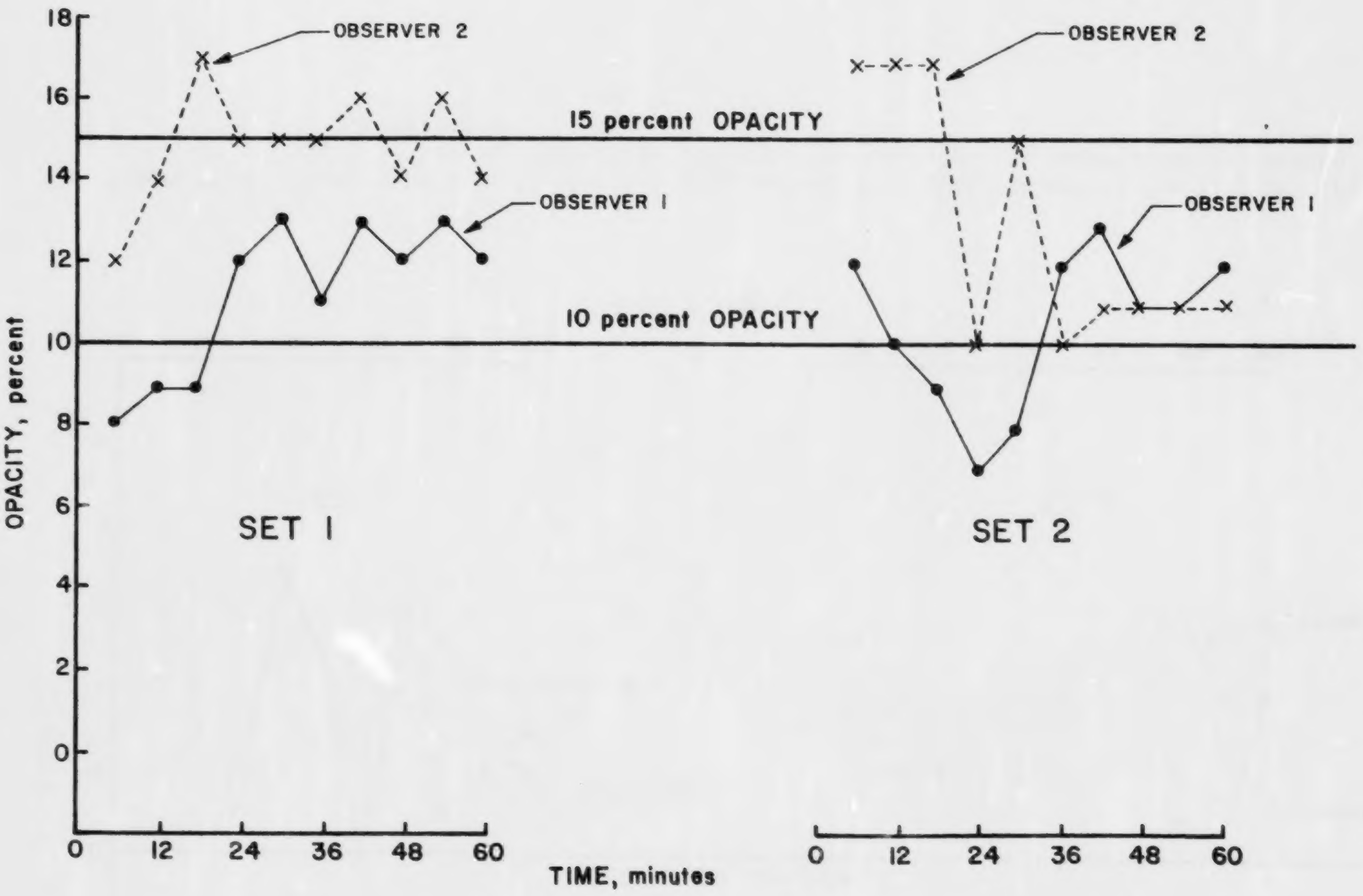


Figure 4-16. Summary of visible emission measurements from best controlled fugitive secondary crushing source (portable-Facility R) by means of wet suppression (according to EPA Method 9).

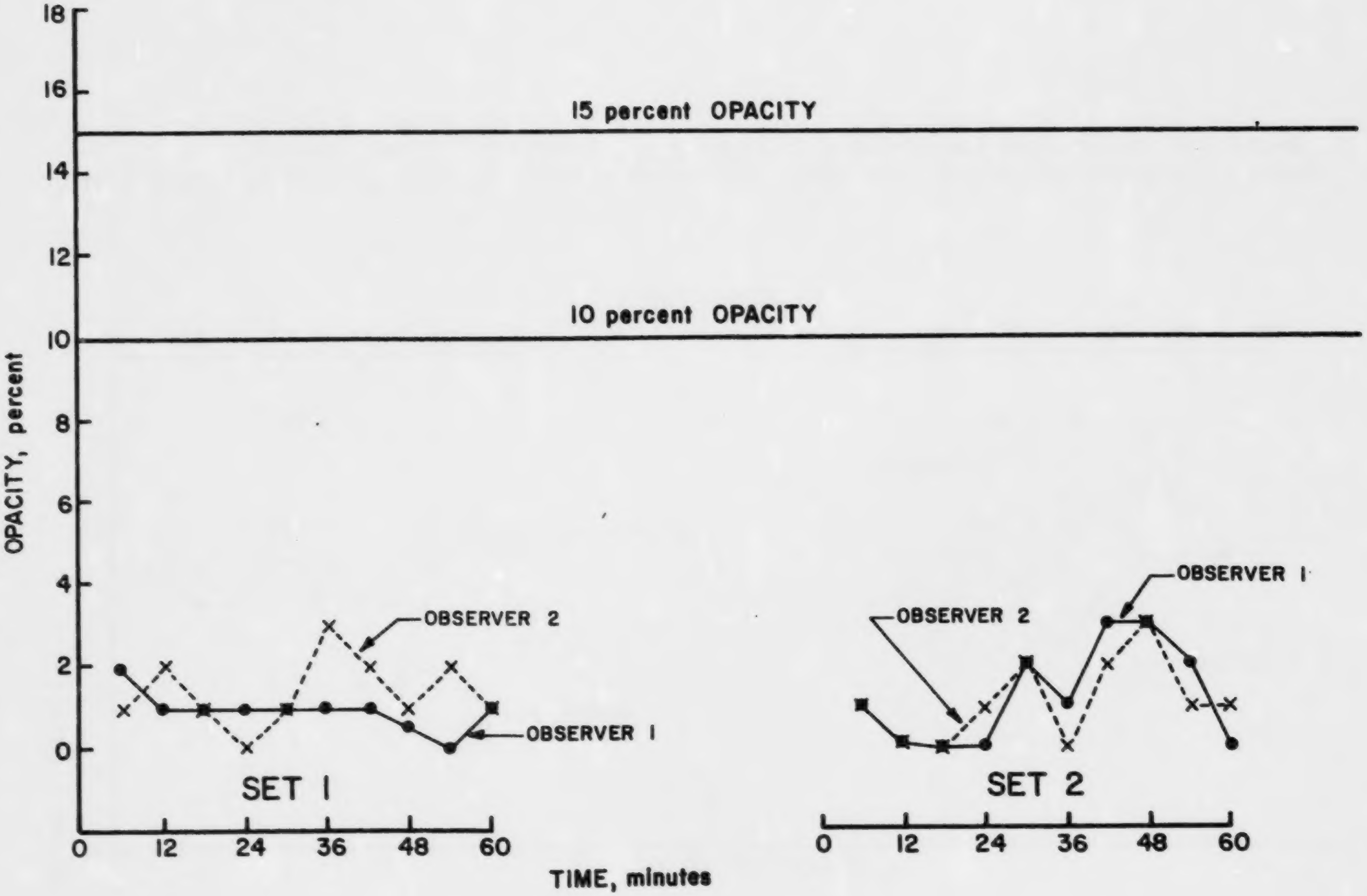


Figure 4-17. Summary of visible emission measurements from best controlled fugitive primary crushing source (stationary-Facility S) by means of wet suppression (according to EPA Method 9).

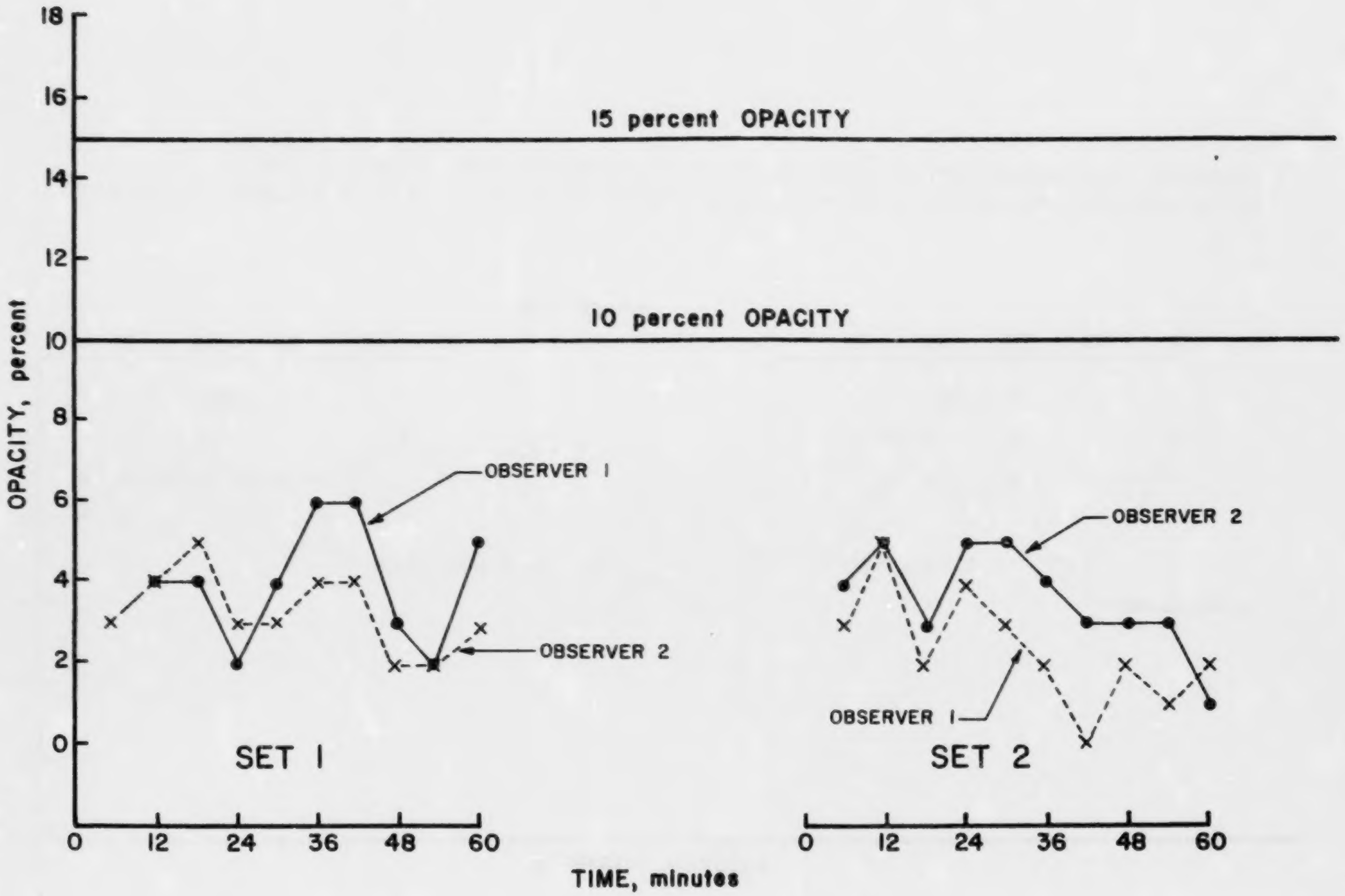


Figure 4-18. Summary of visible emission measurement from best controlled fugitive secondary crusher (small, stationary-Facility S) by means of wet suppression (according to EPA Method 9).

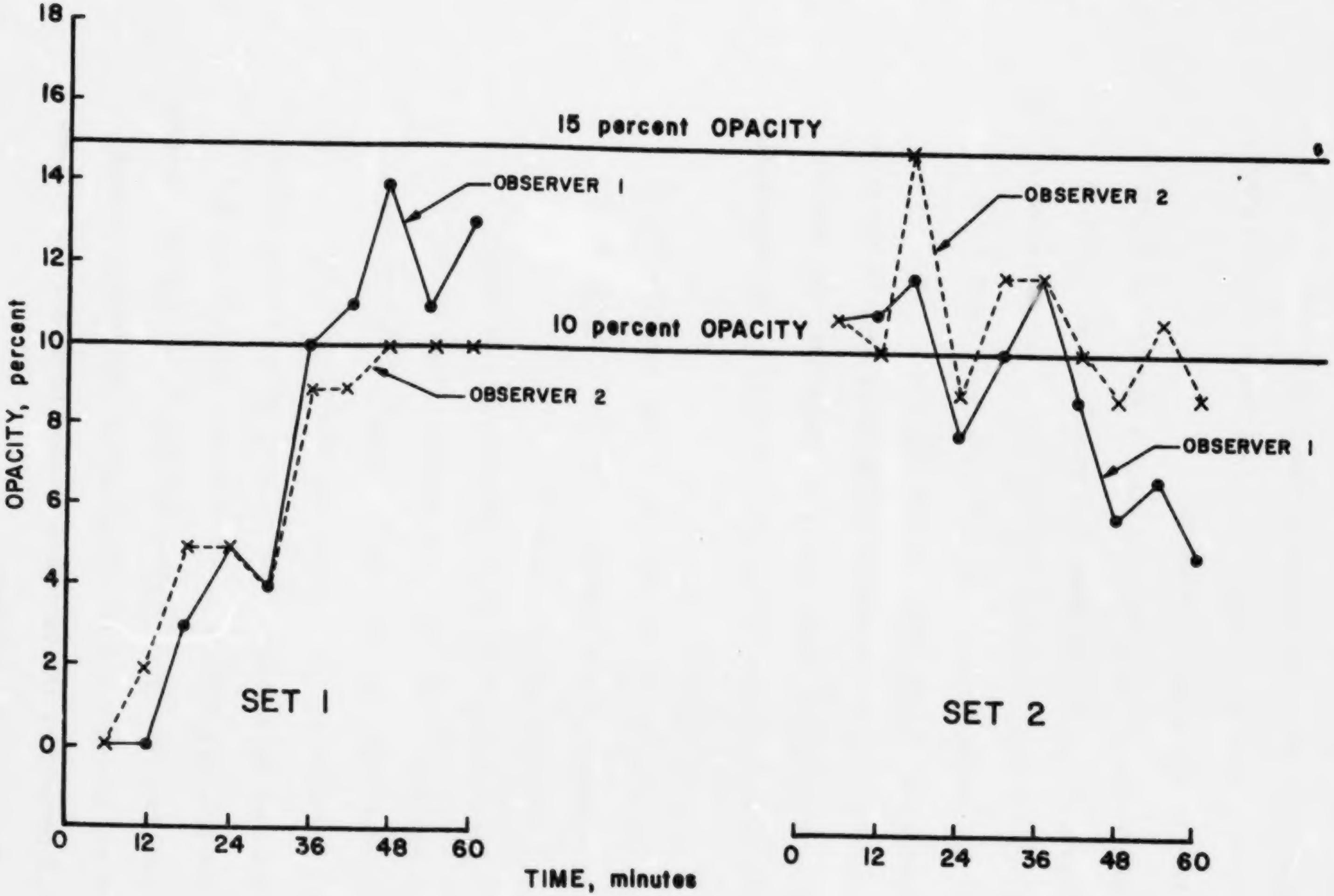


Figure 4-19. Summary of visible emission measurements from best controlled fugitive secondary crushing source (large, secondary-Facility S) by means of wet suppression (according to EPA Method 9).

was no spray bar located near the crusher outlet. It is felt that had the spray bar for the crusher been relocated closer to the crusher then its present position some 5 feet from the crusher, emissions would have dropped below 15 percent opacity for all observer readings.

The positioning and number of spray bars in some of the tested plants may not have been adequate for effective emission control. Plant S, which was judged as the best-controlled plant based on the design and operation of its wet suppression system was at the time of the testing a newly constructed plant with the wet suppression system designed into the plant. Existing plants may encounter difficulties in retrofitting the spray bars in the proper locations due to space limitation or other factors. Therefore, the results from Plant S may not be representative of the effectiveness of wet suppression systems retrofitted to existing plants.

During the periods of observation at facility F (see Appendix C), no visible emissions were observed at two crushers. The two crushers were observed simultaneously for a period of 65 minutes.

Visible emission observations were also conducted at a feldspar crushing installation which had a wet dust suppression system to control particulate emissions generated (see facility G, Appendix C) by crushers, screens, and conveyor transfer points. During the observations the suppression system was used only intermittently, presumably because the ore had sufficient surface moisture from rains the previous day. During the periods of observation, essentially no visible emission were observed Surface moisture contents of the ore were 1.6 to 1.8 percent at the primary crusher discharge; 1.4 to 1.5 percent at the secondary crusher feed; and 1.0 percent at the secondary crusher discharge conveyor.

REFERENCES FOR CHAPTER 4

1. "Rock Products Reference File - Dust Suppression," Rock Products, May 1972, p. 156.

2. Weant, G.E., "Characterization of Particulate Emissions from the Stone-Processing Industry," prepared by Research Triangle Institute for the United States Environmental Protection Agency, Contact No. 68-02-0607-10 May 1975, p. 64.

3. Johnson-March Corporation, Product Literature on Chem-Jet Dust Suppression System, 1071.

4. Courtesy of Johnson-March Corporation.

5. Reference 4.

6. Hankin, M., "Is Dust the Stone Industry's Next Major Problem," Rock Products, April 1967, p. 84.

7. "Air Pollution Control at Crushed Stone Operations," National Crushed Stone Association, February 1976, page V-4.

8. Reference 6, p. 114.

9. Reference 7, page V-5.

10. Anderson, D.M., "Dust Control Design by the Air Induction Technique," Industrial Medicine and Surgery, February 1964, p. 3.

11. Telephone connversation between Mr. Alfred Vervaert, EPA, and Mr. Joe McCorkel, Aggregates Equipment Incorporated, January 28, 1975.

12. Reference 11.

13. Reference 11.

14. American Conference of Governmental Industrial Hygienists, "Industrial Ventilation, A Manual of Recommended Practice," 11th Edition, 1970, p. 5-33.

15. Reference 6, p. 2

16. Reference 14, p. 5-32.

17. Reference 14, p. 5-33.

18. Reference 14, p. 5-31.

19. Reference 14, p. 5-28.

20. "Control Techniques for Particulate Air Pollutants," U.S. Environmental Protection Agency, Publication No. AP-51, January 1969, pp. 46-47.

21. "Source Testing Report - Kentucky Stone Company, Russellville, Kentucky," prepared by Engineering - Science, Incorporated, EPA Report No. 75-STN-3.

22. "Emission Study at a Feldspar Crushing and Grinding Facility," prepared by Clayton Environmental Consultants, Incorporated, EPA Report Number 76-NMM-1.

23. Reference 20.

24. "Air Pollution Engineering Manual," Second Edition, U.S. Environmental Protection Agency, Publication AP-40. p. 128, May 1973.

25. Reference 25, p. 104.

26. Emission Characteristics of the Non-metallic Minerals Industry, Industrial Gas Cleaning Institute, EPA Contract No. 68-02-1473, Task No. 25, July 1977.

27. Reference 20.

28. Billings, C.E., and J. Wilder, Handbook of Fabric Filter Technology In: Fabric Filter System Study (Volume I). GCA Corporation, GCA/Technology Division. Bedford, Massachusetts, Contract No. CPA 22-69-38. December 1970.

29. "Metallic Mineral Processing Plants - Background Information for Proposed Standards, Volume 2" U.S. Environmental Protection Agency, EPA 450/3-81-009b, August 1982.

5. MODIFICATIONS AND RECONSTRUCTIONS

5.1 MODIFICATION

The facilities at non-metallic mineral processing plants that would be subject to the proposed standards are each crusher, grinding mill, screening operation, bucket elevator, belt conveyor, bagging operation, storage bin, enclosed truck loading station, and enclosed railcar loading station. For a change to be termed a modification, it must result in an increase in emissions from any one of these process operations.

Under the modification provisions, actions that would not be considered modifications, regardless of emission increase, include the following:

A. Routine maintenance, repair, and replacement, such as replacement or refurbishing of components subject to high abrasion and impact (crushing surfaces, screening surfaces, conveyor belts, etc.).

B. An increase in the production rate, if the increase can be accomplished without a capital expenditure exceeding the product of the existing facility's Internal Revenue Service annual asset guideline repair allowance of 6.5 percent per year and the facility's basis.

C. An increase in the hours of operation.

D. Use of an alternative raw material, if the existing facility was designed to accomodate such material. Because process equipment (crushers, screens, conveyors, etc.) is designed to accommodate a variety of rock types, any change in raw material feed would not likely be considered a modification.

E. The addition or use of any air pollution control system except when a system is removed or replaced with a system considered to be less effective.

F. The relocation or change in ownership of an existing facility.

The expected impact of the modification provision on existing non-metallic mineral processing facilities should be very slight. No condition is currently foreseen that would allow an existing non-metallic mineral processing facility to be modified under this definition.

When expansions at existing plants take place, usually a completely new crushing/grinding line is added (with the possible exception of the primary crusher). Such an increase in production would not be considered a modification but rather a series of new sources. Primary crushing operations at non-metallic mineral plants usually operate below 100 percent capacity and are capable of handling increased throughput without additional equipment. Under (B) above, an increase in production at the primary crusher would not be considered a modification.

5.2 RECONSTRUCTION

The reconstruction provision is applicable only where replacement of components of an existing facility exceeds 50 percent of the fixed capital cost that would be required to construct a similar new facility and air pollution control techniques are shown to be technologically and economically feasible. For the non-metallic mineral industries, replacement or refurbishing of equipment parts subject to high abrasion and impact such as crushing surfaces, screening surfaces, and conveyor belts are performed on a regular basis and could be considered routine maintenance. The cumulative cost of these repairs to any one piece of equipment over a period of time could exceed 50 percent of the fixed capital cost of entirely new equipment.

6. EMISSION CONTROL SYSTEMS

The alternative control systems that are considered the best combination of the control techniques previously discussed are presented in this chapter. The analysis of environmental effects in Chapter 7 and of economic impacts in Chapter 8 will examine the impacts associated with the alternative emission control systems.

As discussed in Chapter 4, both dry collection and wet suppression systems are considered as viable control alternatives. Unfortunately, the emissions from a wet suppression system are not amenable to measurement and therefore cannot be quantified. In addition, wet suppression systems cannot be used in all cases throughout the industry and therefore cannot be considered a candidate for best technology. Thus, major emphasis of developing the environmental and economic impacts for the non-metallic mineral industry will be placed on dry collection systems and wet suppression systems will be discussed only briefly. Since the dry collection systems are more costly and require more energy (for fans), the impacts on the industry will be overstated as compared to an analysis based on industry use of both dry and wet collection systems.

The model plants which will be analyzed for estimating cost impact and environmental impact are shown in Table 6.1. Two basic models of non-metallic mineral plants were developed. The first model plant consists of crushing operations only, and includes: primary, secondary, and tertiary crushing, three or four screening operations, five to 10 transfer points, and the storage bin loading operation. The second model plant includes both a crushing

Table 6.1 Model Plants for Estimating Environmental and Economic Impact

Plant Size [Mg/hr (TPH)]	Model Plant	Gas Volume to Baghouses [m^3/s (cfm)]	Plant Size [Mg/hr (TPH)]	Model Plant	Gas Volume to Baghouses [m^3/s (cfm)]
9.1 (10)	1	4.8 (10,200)	136 (150)	1	11.8 (25,000)
9.1 (10)	2	4.8 (10,200) 1.9 (4,000)	136 (150)	2	11.8 (25,000) 5.3 (11,300)
22.7(25)	1	5.4 (11,500)	272 (300)	1	18.9 (40,000) 3.8 (8,000)
22.7(25)	2	5.4 (11,500) 2.2 (4,700)	272 (300)	2	18.9 (40,000) 3.8 (8,000) 10.4 (22,600)
68.0(75)	2	8.4 (17,800)	544 (600)	1	4.2 (9,000) 15.1 (32,000) 14.6 (31,000)
68.0(75)	2	8.4 (17,800) 3.2 (6,700)	544 (600)	2	4.2 (9,000) 15.1 (32,000) 14.6 (31,000) 21.2 (45,200)

Notes: ·Model 1 - crusher (primary, secondary, and tertiary), screens (3 or 4), transfer points (5 to 10), and storage bin loading operation.

·Model 2 - crusher (primary, secondary, and tertiary), grinder, screens (3 or 4), transfer points (5 to 10), storage bin loading operation, and bagging machine.

·In all cases, baghouses are used as the control device(s).

operation and a grinding operation--the latter consisting of a grinding mill, classifier or screen, two additional transfer points and a bagging machine. Both model plants use baghouses as the control device(s).

The model plants for analysis consist of 9, 23, 68, 136, 272, and 544 megagrams per hour (Mg/hr) (10, 25, 75, 150, 300 and 600 tons per hour) stationary plants. The portable crushing plant segments of the crushed stone, and sand and gravel industries are discussed in Supplement A.

The process equipment and associated energy requirements and air volumes used in defining the model plants are contained in Table 6.2. The parameters listed are used as the basis for the energy usage calculations presented in Section 7 and the cost and economic impact analysis in Section 8. Parameters for the 272 and 544 Mg/hr (300 and 600 ton/hr) model plants were derived from flow diagrams presented in the industrial literature. Energy requirements and gas volumes for the smaller model plants were calculated from equipment specifications and flow correlations.

The two model plants and six plant sizes are not applicable to each non-metallic mineral industry. The model plant used for each industry, the typical range of plant sizes found in the industry, the typical plant size and the plant sizes which will be used in determining the economic and environmental impacts for each industry are listed in Table 6.3. All the industries employ crushing and grinding operations (Model Plant 2) except crushed and broken stone, sand and gravel, perlite, vermiculite and rock salt. Generally, the size of non-metallic minerals plants is less than 136 Mg/hr (150 TPH) except for plants in the crushed stone, and sand and gravel industries.

Table 6.2 List of Process Equipment Including Energy Requirements and Air Volume Requirements Used in Determining Model Plants

	10 TPH			25 TPH			75 TPH		
Item	Size	Energy Requirement HP	Gas Vol. CFM	Size	HP	CFM	Size	HP	CFM
Primary Crusher	10"x 21" Jaw	35	375	10"x 30" Jaw	60	525	15"x 38"	75	1000
Primary Screen	3 x 4	2	600	3 x 8	5	1200	6 x 10	15	3000
Secondary Crusher	2' cone	25	2000	13 x 59 gyratory	30	1325	13 x 59 gyratory	70	1325
Secondary Screen	3 x 4	5	600	3 x 8	5	1200	6 x 10	15	3000
Tertiary Crusher	24"x 30" Roll	40	1250	24"x 30" Roll	40	1250	10"x 39" Hammermill	200	1350
Tertiary Screen	3 x 4	[illegible]	600	3 x 8	5	1200	6 x 10	15	3000
Feeder					7.5			7.5	
Storage Bin Conveyors	(2) 18" (3)	20	1000	(2) 18" (3)	20	1000	(2) 24" (1) 18" (2)	7 13	1000
Transfer Points	18" (5)		3750	18" (5)		3750	24" (1) 18" (4)		1000 3000
Grinder System	6 x 8 Ball Mill	150	4000	8 x 7 Ball Mill	300	4700	10 x 12 Ball Mill	800	6700
Total - Crushing Plant Only (Model 1)		137	10175		172.5	11450		417.5	17675
Total - Crushing and Grinding (Model 2)		287	14175		472.5	16150		1217.5	24375

Item	150 TPH			300 TPH			600 TPH		
	Size	HP	CFM	Size	HP	CFM	Size	HP	CFM
Primary Crusher	27"x 42" Jaw	150	2500	35"x 46" Jaw	200	3500	50"x 60" Jaw	300	4660
Primary Screen	6 x 12	20	3600	6 x 12	20	3600	6 x 12	20	3600
Secondary Crusher	4' cone	150	3250	4 ½ cone	175	3660	5 ½ cone 5 ½ cone	200 200	6170 6170
Secondary Screen	6 x 12	20	3600	6 x 16	20	4800	6 x 16	20	4800
Tertiary Crusher	13"x 59" Gyratory	125	1325	4' cone 4' cone	150 150	3260 3260	5 ½ cone 5 ½ cone	200 200	6170 6170
Tertiary Screen	6 x 12	20	3600	7 x 20	30	7000	7 x 20 7 x 20	30 30	7000 7000
Feeder		7.5			10			20	
Storage Bin			1500			2500			2500
Conveyors	(3) 30" (1) 24" (2)	12 19.5		(5) 36" (2) 30" (3) 24" (3)	29 48 13		(5) 36" (3) 30" (4)	113 59	
Transfer Points	24" (3) 30" (2)		3000 2500	36" (3) 30" (4) 24" (7)		4500 5000 7000	36" (3) 30" (7)		9000 8750
Grinder System	10 x 12 (2) Ball Mill	1600	11300	10 x 12 (4) Ball Mill	3200	22600	10 x 12 (8) Ball Mill	6400	45200
Total - Crushing Plant Only (Model 1)		524	25399		845	48080		1392	71990
Total - Crushing and Grinding (Model 2)		2124	36699		4045	70680		7792	117190

References:
- Estimating Dust Control Costs for Crushed Stone Plants, Bureau of Mines Report, Rock Products, April, 1975.
- Mineral Processing Flowsheets, Denver Equipment Company, Second Edition.
- Cedarapids Reference Book, Iowa Manufacturing Company, Ninth Pocket Edition.
- Background Information for the Non-Metallic Minerals Industry, PEDCo Environmental Specialists, EPA Contract No. 68-02-1321 Task No. 44, August 31, 1976.
- Chemical Engineers Handbook, 3rd Edition, Perry,, Robert H. (editor), McGraw Hill.
- Pit and Quarry Handbook and Purchasing Guide, 63rd Edition, Pit and Quarry Publications, Incorporated, 1970.
- "Industrial Ventilation, A Manual of Recommended Practice, 11th Edition, American Conference of Governmental Industrial Hygienists, 1970.
- Smith Engineering works, Product Literature on Telsmith Equipment for Mines ... Quarries and Gravel Pits, Bulletin 266 B.

TABLE 6.3. PLANT SIZES FOR THE VARIOUS NON-METALLIC MINERALS INDUSTRIES (METRIC UNITS)

Industry	Plant Model Used	Range Mg/hr	Typical Size* Mg/hr	Model Plant Sizes** Pertinent to the Industry Mg/hr
Crushed & Broken Stone	1	-	272	23,68,136,272,544
Sand & Gravel	1	14-2177	272	23,68,136,272,544
Clay	2	4-136	23	9,23,68,136
Rock Salt	1	-753	68	23,68,136,272,544
Gypsum	2	-	23	9,23,68
Sodium Compounds	2	-204	23	23,68,136,272
Pumice	2	5-30	9	9,23,68
Gilsonite	2	-	9	9,23,68
Talc	2	5-18	9	9,23
Boron	2	31-385	272	23,68,136,272,544
Barite	2	9-45	9	9,23,68
Fluorspar	2	-23	9	9,23
Feldspar	2	5-23	9	9,23
Diatomite	2	8-60	23	9,23,68
Perlite	1	15-54	23	9,23,68
Vermiculite	1	68-272	68	68,75,150,272
Mica	2	-	9	9,23
Kyanite	2	-	9	9,23,68

* These values will be used to estimate the air impact on mass emissions for each industry.

** These values will be used to estimate the economic impact on each industry.

Note: In all cases, baghouses are used as the control device(s).

TABLE 6.3. PLANT SIZES FOR THE VARIOUS NON-METALLIC MINERALS INDUSTRIES (ENGLISH UNITS)

Industry	Plant model used	Range (TPH)	Typical Size* (TPH)	Model Plant Sizes** Pertinent to the Industry (TPH)
Crushed & Broken Stone	1		300	25,75,150,300,600
Sand & Gravel	1	15-2400	300	25,75,150,300,600
Clay	2	4-150	25	10,25,75,150
Rock Salt	1	-830	75	25,75,150,300,600
Gypsum	2	-	25	10,25,75
Sodium Compounds	2	-225	25	25.75.150.300
Pumice	2	5-33	10	10,25,75
Gilsonite	2	-	10	10,25,75
Talc	2	6-20	10	10,25
Boron	2	34-425	300	25.75,150,300,600
Barite	2	10-50	10	10,25,75
Fluorspar	2	-25	10	10,25
Feldspar	2	5-25	10	10,25
Diatomite	2	9-66	25	10,25,75
Perlite	1	16-60	25	10,25,75
Vermiculite	1	75-300	75	75,150,300
Mica	2	-	10	10,25
Kyanite	2	-	10	10,25,75

* These values will be used to estimate the air impact on mass emissions for each industry.

** These values will be used to estimate the economic impact on each industry.

Note: In all cases, baghouses are used as the control device(s).

7. ENVIRONMENTAL IMPACT

An assessment of the incremental impact to the environment associated with the application of the emission reduction systems described in Chapter 4 is presented below. Beneficial and adverse impacts on air, water, solid waste, energy and noise which may be directly or indirectly attributed to the operation of these emission control systems are assessed.

7.1 AIR POLLUTION IMPACT

To determine the true impact of standards of performance on air pollution, one must determine the reduction in air pollution they effect beyond that which would otherwise be achieved by state and local regulations. As noted in Section 3.2.3, present regulations which limit the emission of particulate from non-metallic minerals processing facilities take many forms and vary greatly in stringency and enforcement. For the purpose of this analysis, it is assumed that all non-metallic minerals plants are subject to a general process weight regulation designed to limit particulate emissions from any source. Table 7.1 summarizes the high, low, and typical emission rates allowed under these State process weight regulations. An assessment of the national air pollution impact and the results of dispersion analyses conducted for 12 model plants are presented below.

7.1.1 National Air Pollution Impact

The production of the various non-metallic minerals is projected to increase at compounded annual growth rates of up to six percent through the year 1985. Table 7.2 presents for each non-metallic mineral, the growth

Table 7.1 Allowable Emissions Under General State Process Weight Regulations

Process Weight Rate 10^3 kg/hr (tons/hr.)		Allowable Emissions,[1] kg/hr (lb/hr) High	Low	Typical
0.5	(0.5)	1.3 (2.8)	0.7 (1.6)	1.2 (2.6)
2.3	(2.5)	3.5 (7.7)	2.9 (6.3)	3.4 (7.6)
4.5	(5.0)	6.9 (15.2)	2.7 (6.0)	5.5 (12.0)
9.1	(10.0)	13.7 (30.0)	4.0 (8.7)	8.7 (19.2)
18.1	(20.0)	27.1 (59.7)	5.7 (12.5)	13.9 (30.5)
27.2	(30.0)	30.5 (67.2)	7.1 (15.6)	18.2 (40.0)
54.4	(60.0)	31.1 (68.2)	15.1 (33.3)	21.0 (46.3)
90.7	(100.0)	43.2 (95.2)	13.4 (29.5)	23.2 (51.2)
453.6	(500.0)	119.9 (264.0)	18.2 (40.0)	31.3 (69.0)

TABLE 7.2 GROWTH RATES AND MINERAL PRODUCTION LEVELS FOR THE VARIOUS NON-METALLIC MINERALS INDUSTRIES

Mineral	Estimated 1980 production level		Annual[a] projected growth rate (%)	Estimated 1985 production level	
	10^3 megagrams	1,000 tons		10^3 megagrams	1,000 tons
Crushed and broken stone	981,839	(1,082,292)	4.0	1,194,557	(1,316,774)
Sand and gravel	752,538	(829,531)	1.0	790,926	(871,847)
Clay	52,834	(58,240)	3.5	62,750	(69,171)
Rock salt	16,482	(18,168)	2.0	18,186	(20,046)
Gypsum	9,764	(10,763)	2.0	10,783	(11,886)
Sodium compounds	5,124	(5,648)	2.5	5,800	(6,394)
Pumice	4,193	(4,622)	3.5	4,980	(5,490)
Gilsonite	99	(109)	2.0	111	(122)
Talc	1,065	(1,174)	4.0	1,296	(1,428)
Boron	1,357	(1,496)	5.0	1,731	(1,909)
Barite	1,301	(1,434)	2.2	1,451	(1,600)
Fluorspar	146	(161)	3.0	171	(188)
Feldspar	739	(815)	4.0	900	(992)
Diatomite	678	(747)	5.5	888	(979)
Perlite	779	(859)	4.0	948	(1,045)
Vermiculite	364	(401)	4.0	443	(488)
Mica	148	(163)	4.0	181	(200)
Kyanite	114	(126)	6.0	153	(168)
Total	1,829,564	(2,016,749)		2,096,255	(2,310,726)

rate, the estimated 1980 production level based on the 1975 reported production level, and the 1985 estimated production level. Based on the latest reported (1975) production levels, annual production for all 18 non-metallic minerals was 1605 x 10^6 megagrams (1769 x 10^6 tons) in 1975 and will increase to 1829 x 10^6 megagrams (2016 x 10^6 tons) in 1980, and 2096 x 10^6 megagrams (2311 x 10^6 tons) in 1985. If one assumes that all existing plants are now operating at 80 percent of capacity, then new plants and expansions to existing plants will be required to produce an additional 333 x 10^6 megagrams (368 x 10^6 tons) in production capacity projected for the 5-year period from 1980 through 1985. An assessment of the air pollution impact associated with these capacity additions for each industry segment is presented in Table 7.3. Process steps included in this evaluation are crushing, grinding, sizing, and handling. Handling includes conveying, bagging, storage bin loading and fine product loading. Combustion sources (e.g., dryer or kilns) are not included in the analysis. The largest tonnage reduction is in the crushed and broken stone industry followed by the clay industry and the sand and gravel industry. Reductions in the other industry segments are much smaller.

The following procedure was used to arrive at the numbers listed in Table 7.3. The values for allowable 1985 emissions under existing State standards were developed by applying a typical process weight regulation (see Table 7.1) to a typical plant size (see Table 6.3) for each industry. Using the additional ore processing capacity installed between 1980 and 1985 the 1985 emissions due to the new facilities were then calculated. (A plant having both crushing and grinding operations is assumed to be covered by

TABLE 7.3 SUMMARY OF AIR POLLUTION IMPACT
[megagram/year (ton/year)]

Industry segment	Allowable 1985 emissions under				Reduction impact	
	Existing state regulations		Standards of 0.05 g/dscm (0.02 gr/dscf)		Megagram/ year	(ton/ year)
Crushed and broken stone	21,272	(23,448)	2,923	(3,222)	18,385	(20,266)
Sand and gravel	3,838	(4,231)	527	(581)	3,311	(3,650)
Clay	13,978	(15,409)	549	(605)	13,430	(14,804)
Rock salt	545	(601)	35	(39)	510	(562)
Gypsum	1,440	(1,587)	53	(58)	1,387	(1,529)
Sodium compounds	945	(1,042)	32	(35)	974	(1,007)
Pumice	1,512	(1,666)	93	(102)	1,419	(1,564)
Gilsonite	23	(25)	23	(25)	0	(0)
Talc	444	(489)	28	(31)	415	(458)
Boron	74	(82)	74	(82)	0	(0)
Barite	288	(317)	18	(20)	269	(297)
Fluorspar	48	(53)	9	(10)	39	(43)
Feldspar	309	(341)	9	(10)	300	(331)
Diatomite	301	(332)	11	(12)	290	(320)
Perlite	119	(131)	(7)	(8)	112	(124)
Vermiculite	25	(28)	3	(3)	23	(25)
Mica	63	(69)	9	(10)	52	(59)
Kyanite	76	(84)	9	(10)	67	(74)
Total	45,337	(49,976)	4,412	(4,863)	40,926	(45,113)

a process weight regulation which is twice that presented in Table 7.1). The additional ore processing capacity was determined for each industry by multiplying the additional industry capacity (1985 capacity minus 1980 capacity) by the ore to product ratio for each industry. For industries such as crushed stone, sand and gravel, clay and talc, the ore to product ratio is 1.0. Most industry values range between 1.0 and 2.0 with a few [boron (5.8), vermiculite (4.0), fluorspar (3.0), mica (4.2)] ranging above 3. The values for allowable 1985 emissions under a potential NSPS were calculated using the same procedure except that a gas volume was assigned for the specified plant size and the value 0.05 g/dscm (0.02 gr/dscf) was used to calculate the emission level in terms of a process weight rate. The reduction impact is the difference between the allowable 1985 emissions due to the State regulations and the potential NSPS for new capacity additions.

Assuming that all states enforced standards equivalent to the typical process weight regulations, capacity additions over the 5-year period 1980-1985 would result in the emission of an additional 45,337 megagrams (49,976 tons) of particulate in the year 1985. If standards of performance are promulgated at the level of 0.05 g/dscm (0.02 gr/dscf), then only an additional 4,412 megagrams (4,863 tons) of particulate emissions would result. Consequently, the national impact in air pollution reduction effected by standards of performance if promulgated at the level of 0.05 g/dscm (0.02 gr/dscf) would be on the order of 40,926 megagrams (45,113 tons) of particulate in the year 1985. It should be noted that because of the lack of uniformity of existing state regulations and the discretionary manner in which these regulations are enforced, the level of control at existing plants is very likely below that established by the assumptions that all existing plants are subject to the typical process weight regulation and that these regulations are universally enforced. In addition, the air pollution impact assessed above does not account for that portion of existing equipment which would be replaced with new equipment, therefore becoming subject to standards of performance due to obsolescence. As a result, the true impact would probably exceed that presented above.

7.1.2 Dispersion Analysis

Dispersion calculations were performed on six model plants with typical production capacities of 9, 23, 68, 136, 272, and 544 megagrams per hour (10, 25, 75, 150, 300, and 600 TPH). For each model, calculations were performed for two levels of emission control which included that achievable using best control technology and that required to meet typical State regulations. A dry collection system is assumed to be used to meet both levels of control because: (a) emissions when wet suppression is used are discharged in an unconstrained manner (not discharged through a stack); and (b) because emission rates achievable by wet suppression were not determined in this study and are not otherwise available. Results of the analysis, including characteristics of the models used and assumptions made, are presented below.

7.1.2.1 Model Plant Characteristics - The model plants selected are identical to those used in the following chapter in assessing the economic impact. As in Chapter 8, the 9,23,68 and 136 Mg/hr (10, 25, 75, and 150 TPH) plants are assumed to use two fabric filters for control and the 272 and 544 Mg/hr

(300 and 600 TPH) plants are assumed to use three and four fabric filters, respectively. (One less fabric filter is used in each model plant if a grinding operation is not employed). It is also assumed that proper hooding and indraft velocities are used so that all emissions from the process equipment are captured. Figure 7.1 shows the physical configuration of the discharge points for each model. For the 9, 23, 68, and 136 Mg/hr (10, 25, 75, and 150 TPH) plants, the No. 1 stack is from a fabric filter controlling emissions from the crushing operation and its associated screening and handling operations, and the No. 2 stack is from a second fabric filter controlling the grinding operation and its associated screening and handling operations. The 272 Mg/hr (300 TPH) plant is controlled by three fabric filters; one for the primary crusher, the second for the remaining crushing operations; (i.e., secondary and tertiary crushing and screening and associated material handling operations), and the third for the grinding system. The 544 Mg/hr (600 TPH) plant is controlled by four fabric filters; one for the primary crusher, the second for the secondary crusher and screens, the third for the tertiary crushers and finishing screens, and the fourth for the grinding system.

The dispersion calculations were performed assuming two levels of emission control: 0.05 g/m^3 (0.02 gr/dscf) and the process weight regulation for Ohio which was chosen as typical of State regulations. The emission source characteristics for the model plants are presented in Table 7.4. A control efficiency of about 95 percent would be required to meet the typical process weight regulation and better than 99 percent to reflect that achievable using best control.

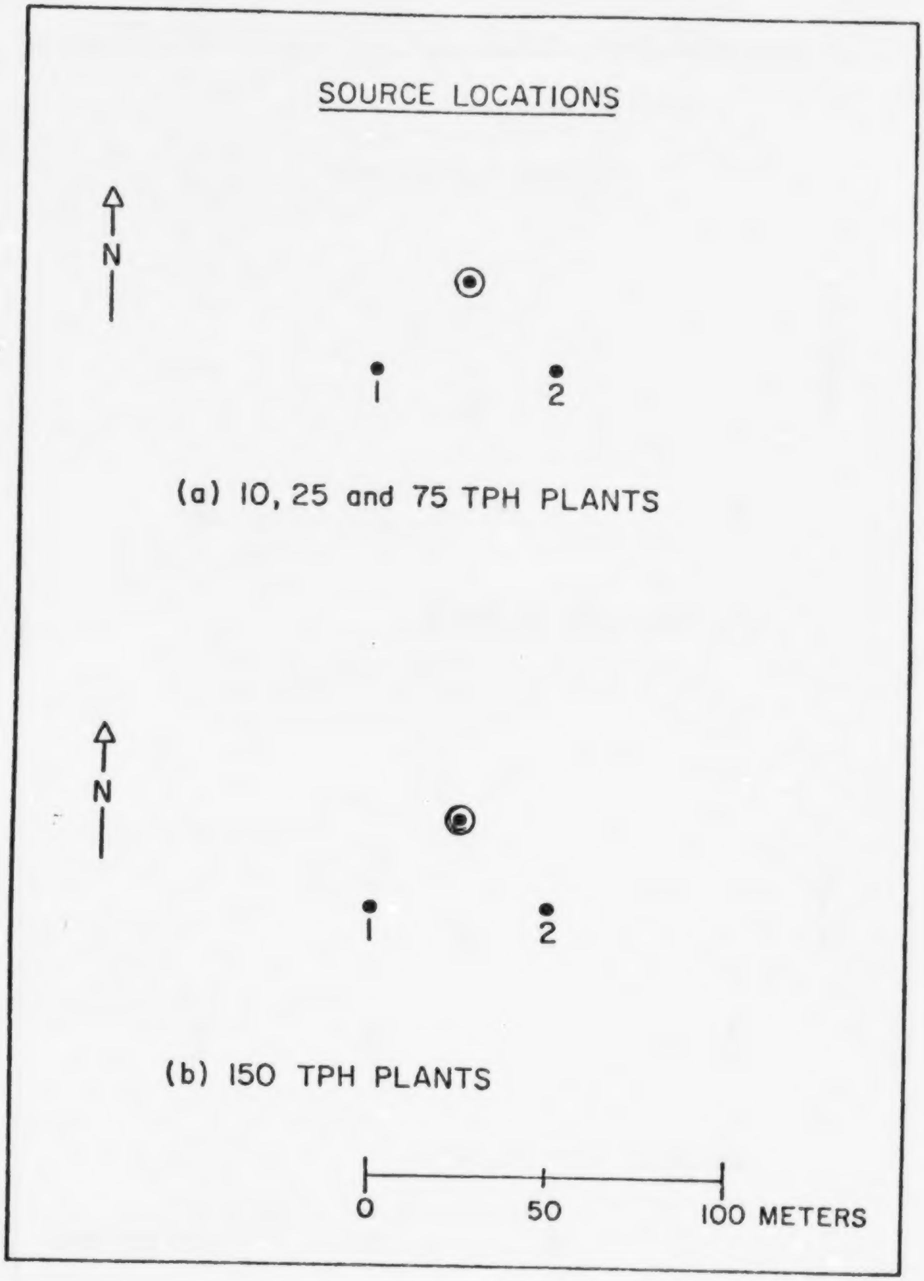

SOURCE LOCATIONS
N
1
2
(a) 10, 25 and 75 TPH PLANTS
N
1
2
(b) 150 TPH PLANTS
0
50
100 METERS

Figure 7.1 Plant layouts showing the number and locations of the sources (stacks) specified for each plant size. The filled circles show the locations of the individual stacks. The ⦿ symbols show the origins of the receptor grids used in the model calculations.

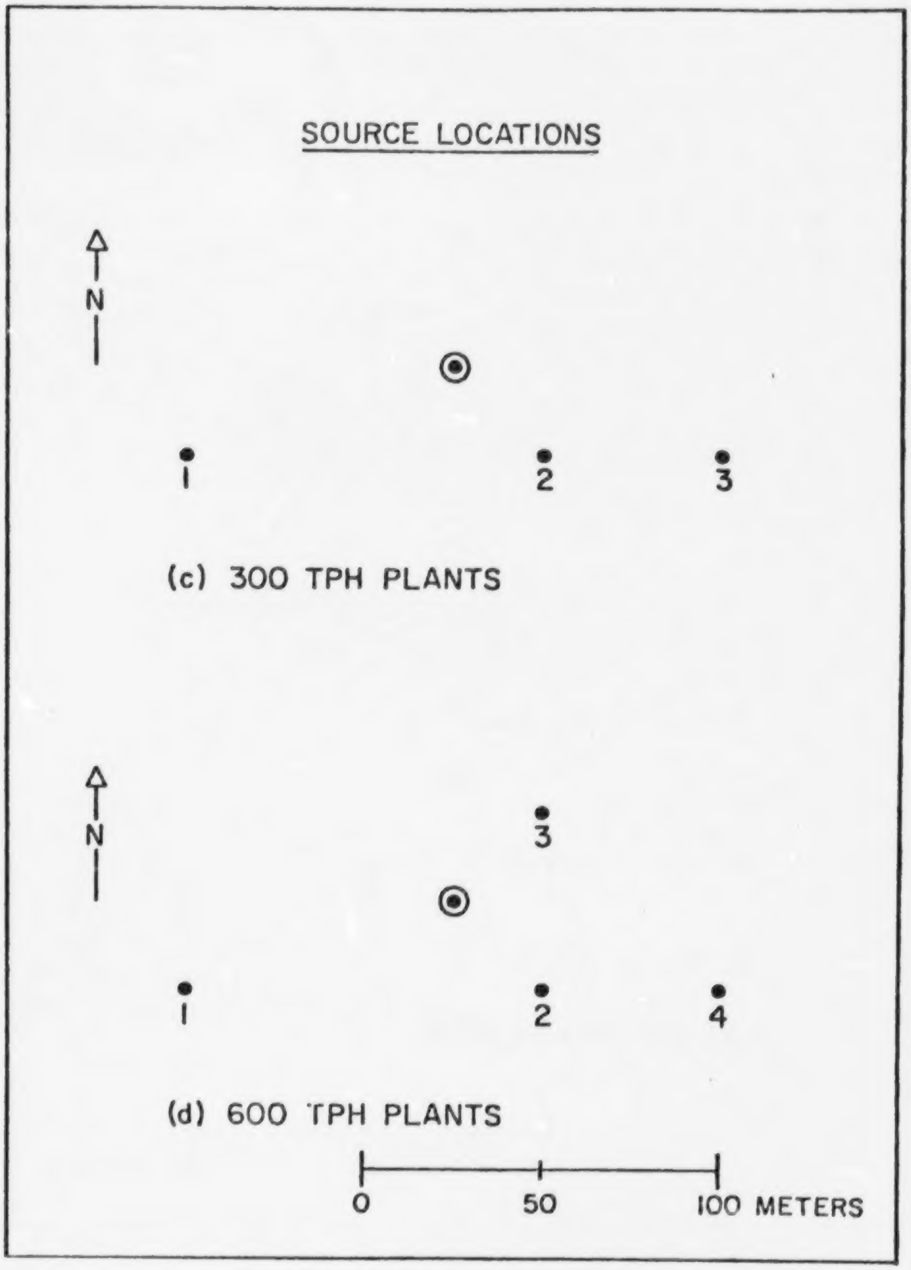

SOURCE LOCATIONS
N
1
2
3
(c) 300 TPH PLANTS
N
3
1
2
4
(d) 600 TPH PLANTS
0
50
100 METERS

Figure 7.1 (continued)

Table 7.4

STACK AND EMISSIONS DATA
(Metric Units)

Case[a]	Plant Size (Mg/hr)	Stack Number	Stack Diameter (m)	Stack Height (m)	Stack Exit Velocity (m/sec)	Stack Exit Temperature (°K)	Particulat Emission Rate (g/sec)
1	9	1	0.58	9.1	18.0	ambient	0.24
		2	0.33	12.2	23.0	ambient	0.09
2	9	1	0.58	9.1	18.0	ambient	2.42
		2	0.33	12.2	23.0	ambient	2.42
3	23	1	0.61	9.1	18.0	ambient	0.27
		2	0.37	12.2	23.0	ambient	0.11
4	23	1	0.61	9.1	18.0	ambient	4.46
		2	0.37	12.2	23.0	ambient	4.46
5	68	1	0.76	9.1	18.0	ambient	0.41
		2	0.43	12.2	23.0	ambient	0.15
6	68	1	0.76	9.1	18.0	ambient	6.10
		2	0.43	12.2	23.0	ambient	6.10
7	136	1	0.79	9.1	23.0	ambient	0.58
		2	0.55	12.2	23.0	ambient	0.26
8	136	1	0.79	9.1	23.0	ambient	6.74
		2	0.55	12.2	23.0	ambient	6.74
9	272	1	0.58	6.1	15.0	ambient	0.18
		2	1.07	9.1	23.0	ambient	0.92
		3	0.76	12.2	23.0	ambient	0.52
10	272	1	0.58	6.1	15.0	ambient	1.52
		2	1.07	9.1	23.0	ambient	6.06
		3	0.76	12.2	23.0	ambient	6.10
11	544	1	0.61	6.1	15.0	ambient	0.21
		2	0.91	9.1	23.0	ambient	0.74
		3	0.91	9.1	23.0	ambient	0.71
		4	1.10	12.2	23.0	ambient	1.04
12	544	1	0.61	6.1	15.0	ambient	1.11
		2	0.91	9.1	23.0	ambient	3.84
		3	0.91	9.1	23.0	ambient	3.96
		4	1.10	12.2	23.0	ambient	6.72

---

[a] Odd numbered cases are based on an emission level of 0.05 g/m^3 (0.02 gr/dscf). Even numbered cases are based on allowable emissions if typical State process weight regulations are used.

Table 7.4

STACK AND EMISSIONS DATA
(English Units)

Case[a]	Plant Size (tph)	Stack Number	Stack Diameter (ft)	Stack Height (ft)	Stack Exit Velocity (ft/min)	Stack Exit Temperature (°F)	Particulate Emission Rate (lb/hr)
1	10	1	1.9	30	356	ambient	1.9
		2	1.0	40	455	ambient	0.7
2	10	1	1.9	30	356	ambient	19.2
		2	1.0	40	455	ambient	19.2
3	25	1	2.0	30	356	ambient	2.1
		2	1.2	40	455	ambient	0.9
4	25	1	2.0	30	356	ambient	35.4
		2	1.2	40	455	ambient	35.4
5	75	1	2.5	30	356	ambient	3.3
		2	1.4	40	455	ambient	1.2
6	75	1	2.5	30	356	ambient	48.4
		2	1.4	40	455	ambient	48.4
7	150	1	2.6	30	455	ambient	4.6
		2	1.8	40	455	ambient	2.1
8	150	1	2.6	30	455	ambient	53.5
		2	1.8	40	455	ambient	53.5
9	300	1	1.9	20	300	ambient	1.4
		2	3.5	30	455	ambient	7.3
		3	2.5	40	455	ambient	4.1
10	300	1	1.9	20	300	ambient	12.1
		2	3.5	30	455	ambient	48.1
		3	2.5	40	455	ambient	48.4
11	600	1	2.0	20	300	ambient	1.7
		2	3.0	30	455	ambient	5.9
		3	3.0	30	455	ambient	5.6
		4	3.6	40	455	ambient	8.3
12	600	1	2.0	20	300	ambient	8.8
		2	3.0	30	455	ambient	30.5
		3	3.0	30	455	ambient	31.4
		4	3.6	40	455	ambient	53.3

---

[a] Odd numbered cases are based on an emission level of 0.05 g/m^3 (0.02 gr/dscf). Even numbered cases are based on allowable emissions if typical State process weight regulations are used.

7.1.2.2 The Dispersion Model and Meteorological Considerations - The dispersion model used to analyze the air pollution impact of the plants described above is the modified Single-Source (CRSTER) Model developed by the Meteorology and Assessment Division, EPA. The dispersion analysis was performed by H. E. Cramer Company, Incorporated.[3]

A preliminary analysis showed that maximum short-term ground-level concentrations produced by emissions from stacks of the type listed in Table 7.4 are most likely to occur during periods of light-to-moderate wind speeds and persistant wind directions in combination with neutral stability. These meteorological conditions are quite common in the Pittsburgh, Pennsylvania area. Also, non-metallic minerals processing plants are located in the vicinity of Pittsburgh. Consequently, it was decided that the surface and upper-air meteorological data for the Greater Pittsburgh Airport were representative and should be used to develop the meteorological inputs required for the dispersion-model calculations. Because the plants are assumed to be located outside the Pittsburgh urban area, a rural location was assumed in the model calculations. The prevailing wind directions in the Pittsburgh area during periods of neutral D stability are from the west. In order to maximize the superposition of plumes from individual sources under worst-case meteorological conditions, all plant configurations were given an east-west orientation (see Figure 7.1).

The results of the preliminary analysis also showed that the maximum short-term ground-level concentrations produced by emissions from the sources listed in Table 7.4 can be expected to occur at downwind distances ranging from less than 300 meters (330 yards) to about 900 meters (985 yards). The property boundaries of the six plants are assumed to be a minimum distance of 300 meters from any stack. For the purposes of this study, only ground-level particulate concentrations that occur at and beyond the plant property boundaries were used in assessing the air quality impact of plant emissions.

From a consideration of the results of the preliminary analysis and the fact that only off-property ground-level particulate concentrations are of concern, two receptor grids were constructed for calculations. The ⊙ symbols in Figure 7.1 show the origins of these receptor grids. The receptor grid used in the model calculations for the 9, 23, 68, and 136 Mg/hr (10, 25, 75, and 150 TPH) plants comprised seven concentric receptor rings with radii of 0.335, 0.4, 0.5, 0.6, 0.8, 1.0 and 1.5 kilometers (366, 437, 547, 656, 875, 1094, and 1640 yards). The receptor grid used in the model calculations for the 272 and 544 Mg/hr (300 and 600 TPH) plants comprised six concentric receptor rings with radii of 0.38, 0.5, 0.6, 0.8, 1.0 and 1.5 kilometers (415, 657, 656, 875, 1094 and 1640 yards). All receptor grid points were assumed to be at the same elevation as plant grade. Thus the only terrain effects included in the model calculations are those implicitly contained in the meteorological data from the Greater Pittsburgh Airport.

7.1.2.3 Results and Discussion of Dispersion Calculations - Maximum 24-hour average and annual-average concentrations are presented in Tables 7.5 & 7.6. All 24-hour and annual maximums were located at either 0.3 or 0.4 kilometer (328 or 437 yard) from the plant. Generally, for each case, less than 10

Table 7.5

ESTIMATED MAXIMUM 24-HOUR AND ANNUAL GROUND-LEVEL PARTICULATE CONCENTRATION DUE TO EMISSIONS FROM THE PROCESS SOURCES IN THE MODEL NON-METALLIC MINERALS PLANTS HAVING BOTH CRUSHING AND GRINDING OPERATIONS

Plant Size [Mg/hr (tons/hour)]	Case[a]	24-Hour Average: Distance to Maximum (Km)	24-Hour Average: Maximum Concentration ($\mu g/m^3$)	Annual Average: Distance to Maximum (Km)	Annual Average: Maximum Concentration ($\mu g/m^3$)
9 (10)	1	0.3	14	0.2	2
	2	0.3	200	0.3	16
23 (25)	3	0.3	15	0.3	2
	4	0.3	354	0.3	28
68 (75)	5	0.3	20	0.3	2
	6	0.3	430	0.3	34
136 (150)	7	0.4	24	0.3	2
	8	0.3	383	0.3	31
272 (300)	9	0.4	40	0.4	4
	10	0.4	279	0.4	27
544 (600)	11	0.4	64	0.4	5
	12	0.4	363	0.4	28

[a] Odd number cases are based on an emission level of 0.05 g/m^3 (0.02 gr/dscf). Even number cases are based on allowable emissions under typical State process weight regulations (as shown in Table 7.1)

Table 7.6

ESTIMATED MAXIMUM 24-HOUR AND ANNUAL GROUND-LEVEL PARTICULATE CONCENTRATION DUE TO EMISSIONS FROM THE PROCESS SOURCES IN THE MODEL NON-METALLIC MINERALS PLANTS HAVING ONLY CRUSHING OPERATIONS

		24-Hour Average		Annual Average	
Plant Size [Mg/hr (tons/hour)]	Case[a]	Distance to Maximum (Km)	Maximum Concentration ($\mu g/m^3$)	Distance to Maximum (Km)	Maximum Concentration ($\mu g/m^3$)
9 (10)	1	0.3	10	0.2	1
	2	0.3	107	0.3	8
23 (25)	3	0.3	11	0.3	1
	4	0.3	191	0.3	14
68 (75)	5	0.3	15	0.3	1
	6	0.3	223	0.3	17
136 (150)	7	0.4	16	0.3	1
	8	0.3	187	0.3	15
272 (300)	9	0.4	29	0.4	3
	10	0.4	208	0.4	16
544 (600)	11	0.4	48	0.4	4
	12	0.4	259	0.4	20

[a] Odd number cases are based on an emission level of 0.05 g/m^3 (0.02 gr/dscf). Even number cases are based on allowable emissions under typical State process weight regulations (as shown in Table 7.1)

percent of the days per year had 24-hour average concentrations exceeding 70 percent of the maximum concentration shown in the Table.

The national primary ambient air quality standards for particulate matter, as published in the Federal Register, Volume 36, No. 84, April 30, 1971, are:

a. 75 micrograms per cubic meter--annual geometric mean;

b. 260-micrograms per cubic meter--maximum 24-hour concentration not to be exceeded more than once a year.

Assuming a pristine atmosphere, the data presented in Table 7.5 indicate that for all cases, excluding emissions from sources other than the stack, a plant meeting an emission limitation of 0.05 g/m^3 (0.02 gr/dscf) would meet the ambient air quality standards. In comparison, any plant with a production rate above 9 Mg/hr (10 TPH) which just meets the typical process weight regulation, even though it may require a 95 percent reduction from uncontrolled levels would exceed the ambient air quality standards for the 24-hour average.

The dispersion results presented are only for plant process facilities under consideration. Process operations common to most plants which are not covered by the proposed standard include drilling, blasting, loading at the mine, hauling, stockpiling, conveying (other than transfer points), and windblown dust from stockpiles, roads, and plant yards. These operations are not included because they are not amenable to control using the emission control techniques upon which the proposed standards are based. They are, however, significant sources of particulate matter emissions. Methods for controlling emissions from these operations are discussed in the document entitled "Air Pollutant Control Techniques for the Crushed and Broken Stone Industry" available from the EPA Library (MD-35), Research Triangle Park, North Carolina 27711, telephone number (919) 541-2777.

7.2 WATER POLLUTION IMPACT

The almost exclusive utilization of dry collection techniques (particulate capture combined with a dry emission control device) for control generates no water effluent discharge. In cases where wet dust suppression techniques could be used, the water adheres to the material processed until it evaporates. Wet suppression systems, therefore, would not result in a water discharge.[4] Consequently, emission standards for the non-metallic minerals industry will have no water pollution impact.

7.3 SOLID WASTE DISPOSAL IMPACT

Disposition of quarry, plant and dust collector waste materials depends somewhat upon State and local government and corporate policies. When fabric filter systems are used, about 1.4 megagrams (1.6 tons) of solid waste are collected for every 250 megagrams (278 tons) processed.* In many cases this material can be recycled back into the process, sold, or used for a variety of purposes.

Where no market exists for the collected fines, they are typically disposed of in the mine or in an isolated location in the quarry. A 544 Mg/hr (600 TPH) crushing plant using dry collection for control would generate about

---

*Estimate based on the difference between controlled and uncontrolled emission factors.

27.6 megagrams (30 tons) of waste over an eight hour period. This is about 0.5 percent of the plant throughput. Generally, the collected fines are discharged to a single haul truck at the end of the day and transported to the quarry for disposal. This dumping and transporting can be a source of fugitive dust if these operations are not protected from the wind or controlled by wet suppression. No subsequent air pollution problems should develop provided the waste pile is protected from wind erosion.

Consequently, it is EPA's judgment that the application of dry controls in the non-metallic minerals industry will not have a significant solid waste disposal impact. Where wet dust suppression can be used, no solid waste disposal problem exists over that resulting from normal operation.

7.4 ENERGY IMPACT

The implementation of standards of performance for the non-metallic minerals industry will necessarily result in an increase in energy usage. Generally, the energy impact of alternative control systems and standards is assessed by determining the additional energy consumption (type and amount) above that which would be necessitated by existing State regulations. For the non-metallic minerals industry, however, because of the non-uniformity of current State regulations and the degree of interpretation necessary for enforcement, such an approach would likely substantially understate the true impact on the industry. An alternative approach is to assess the energy impact against an estimate of the current status (type and extent) of existing control across the industry. Because of the size of this industry, however, any such estimates for the non-metallic minerals industry would be subject to considerable uncertainty. Consequently, the energy impact analysis presented below, like the economic impact analysis presented in Chapter 8, is gauged against an assumed baseline existing control of "no control." In this way, the resultant energy impact will have a liberal bias which, if determined to be reasonable, will assure that the true impact is not adverse.

The energy requirements both with and without air pollution controls for six typical plant sizes are shown in Tables 7.7 and 7.8. The model plants selected are identical to those used for the cost and dispersion analyses. The energy requirements reported are for plants with both crushing and grinding operations (Table 7.7) and for plants having crushing operations only (Table 7.8).

A 9 Mg/hr (10 TPH) plant with both crushing and grinding operations and with no controls would require motors with horsepower rating totaling about 214 Kw (287 hp) to operate. Complete fabric filter control would require an additional 30 Kw (40 hp), or an increase in plant power consumption of about 14 percent. For the 23 to 544 Mg/hr (25 to 600 TPH) plants, the application of a dry collection system would increase power consumption by about 5 to 10 percent.

Table 7.7 ENERGY REQUIREMENTS FOR MODEL NON-METALLIC MINERALS PLANTS HAVING CRUSHING AND GRINDING OPERATIONS [KILOWATTS (HORSEPOWER)]

Plant Size [Mg/hr (TPH)]	Uncontrolled	Fabric Filter Controlled	Percent Energy Increase (%)
9 (10)	214 (287)	244 (327)	13.9
23 (25)	353 (473)	387 (519)	9.7
68 (75)	908 (1218)	966 (1296)	6.4
136 (150)	1584 (2124)	1666 (2234)	5.2
272 (300)	3016 (4045)	3170 (4252)	5.1
544 (600)	5810 (7792)	6098 (8177)	4.9

Table 7.8 ENERGY REQUIREMENTS FOR MODEL NON-METALLIC MINERALS PLANTS HAVING CRUSHING OPERATIONS ONLY [KILOWATTS (HORSEPOWER)]

Plant Size [Mg/hr (TPH)]	Uncontrolled	Fabric Filter Controlled	Percent Energy Increase (%)
9 (10)	102 (137)	123 (165)	20.4
23 (25)	129 (173)	153 (205)	18.5
68 (75)	312 (418)	356 (478)	14.4
136 (150)	391 (524)	450 (604)	15.4
272 (300)	630 (845)	737 (989)	17.0
544 (600)	1038 (1392)	1232 (1652)	18.7

For the 9 to 544 Mg/hr (10 to 600 ton/hr) plants with only crushing operations, the application of a dry collection system would increase power consumption between 14 and 20 percent. It is interesting to note that a 544 Mg/hr (600 ton/hr) crushing plant using a combination of both wet and dry controls sufficient to meet most existing State regulations would likely require an additional 75 kW (100 hp) or about a 7 percent increase in power consumption. Complete fabric filter control for this same plant would require a 7 percent increase in power consumption when compared to a plant achieving the typical State regulations.

The estimated additional energy requirement to meet the added demand for non-metallic minerals projected for the year 1985 would be about 0.805 million megawatt-hours in the absence of any air pollution controls. In contrast, if fabric filter controls were installed on all capacity additions (including those obtained from new plants and expansions to existing plants), the estimated additional energy demand would increase to about 0.928 million megawatt-hours. Consequently, the net increase in energy consumption for the year 1985 which would result from the installation of emission control would be about 0.123 million megawatt-hours or 15 percent over that which would otherwise be required to meet the projected capacity additions without controls. When compared to forecasts for national demand of electrical energy alone in 1985 (4.1 billion megawatt-hours), this resultant increase in energy consumption is equivalent to approximately 3×10^{-3} percent of that projected to be consumed nationally.[6]

In addition, the energy impact on each of the 18 affected non-metallic industries has been calculated in Table 7.9. The impacts of energy usage of controlled versus uncontrolled new facilities was calculated to be 0.123 million megawatts for the year 1985. The resultant increase in particulate emissions generated by power plants in the production of the additional 0.123 million megawatts of required power for the control equipment was calculated to be 51 Mg/year (56 ton/year) in 1985 using the allowable emission rate standard of 0.03 lb/10^6 Btu input. It is concluded, therefore, that this increase of particulate emissions from power plants would be more than offset by the potential savings in particulate emissions generated by the non-metallic industry under an NSPS (41,000 Mg/year or 45,000 ton/year particulate).

7.5 NOISE IMPACT

When compared to the noise emanating from crushing and grinding process equipment, any additional noise from properly designed exhaust fans for the control system will be insignificant. Consequently, no significant noise impact is anticipated due to the implementation of standards of performance for non-metallic minerals plants.

TABLE 7.9 ENERGY IMPACT ON INDIVIDUAL NON-METALLIC INDUSTRIES UNDER PROPOSED NSPS

Industry	Increased capacity 1980-1985		Typical plant* size		Number of additional typical plants required	Energy required per typical controlled plant (kW)	Energy required per typical uncontrolled plant (kW)	Impact on each industry (kW)
	10³ Mg/yr	(10³ ton/yr)	Mg/hr	(ton/hr)				
Crushed stone	212,718	(234,481)	272	(300)**	391	737	630	41,837
Sand and gravel	38,388	(42,316)	272	(300)**	71	737	630	7,597
Clay	9,916	(10,931)	23	(25)	52	387	353	1,768
Rock salt	1,704	(1,878)	68	(75)**	13	356	312	572
Gypsum	1,019	(1,123)	23	(25)	5	387	353	170
Sodium compounds	676	(745)	23	(25)	3	387	353	102
Pumice	787	(868)	9	(10)	10	244	214	300
Gilsonite	12	(13)	9	(10)	0	244	214	0
Talc	231	(255)	9	(10)	3	244	214	90
Boron	374	(412)	272	(300)	0	3,170	3,016	0
Barite	150	(165)	9	(10)	1	244	214	30
Fluorspar	25	(28)	9	(10)	1	244	214	30
Feldspar	161	(177)	9	(10)	1	244	214	30
Vermiculite	210	(231)	68	(68)**	1	356	312	44
Mica	169	(186)	9	(10)	3	244	214	90
Kyanite	79	(87)	9	(10)	1	244	214	30
Diatomite	33	(36)	23	(25)	1	387	353	34
Perlite	39	(43)	23	(25)**	1	153	128	25
Total	266,691	(294,275)			558			52,749

*Based on plant operating schedule of 8,400 hours/year.

**Based on plant operating schedule of 2,000 hours/year.

REFERENCES FOR CHAPTER 7

1. "Analysis of Final State Implementation Plans - Rules and Regulations," APTD-1334, EPA Contract No. 68-02-0248, July 1972, pp. 29-31.
2. Commodity Data Summaries Annual, 1977, U. S. Bureau of Mines.
3. "Dispersion - Model Analysis of the Air Quality Impact of Particulate Emissions From Non-Metallic Minerals Processing Plants," prepared by H. E. Cramer Company, Incorporated, for the U. S. Environmental Protection Agency, December 1976.
4. "Draft Development Document for Effluent Limitations Guidelines and Standards of Performance - Mineral Mining and Processing Industry - Volume I (Minerals for the Construction Industry), prepared by Versar, Incorporated, for the U. S. Environmental Protection Agency, Contract No. 68-01-2633, January 1975, p. V-3.
5. "Source Testing Report - Essex Bituminous Concrete Corporation, Dracut, Massachusetts," prepared by Roy F. Weston, Incorporated, EPA Report No. 75 STN-2, December 27, 1974.
6. Dupree, Walter G., and West, James A., "United States Energy through the Year 2000," U. S. Department of the Interior, December, 1972, p. 19.

8. ECONOMIC IMPACT

8.0 SUMMARY

The effect of NSPS control costs on the 18 non-metallic minerals industries was evaluated by first screening each industry for potentially significant impacts. A potentially significantly impacted industry was considered to be any industry which had a plant whose per unit production cost could be increased by 2% or more because of NSPS control costs. This screening analysis consisted of measuring the effect of annualized control cost for the smallest size model plant in each industry (therefore the highest per unit control cost and worst case situation) on the average selling price of the mineral. On the basis of this screening six minerals were selected for further evaluation:

- Pumice
- Sand and gravel
- Crushed stone
- Common clay
- Gypsum
- Perlite

These six minerals were evaluated by developing a discounted cash flow (DCF) analysis for each model new plant size in each industry and also for expansion plant sizes in the common clay and gypsum industries. DCF is an investment decision analysis which shows the economic feasibility of a planned capital investment project over the life of the project.

The DCF analysis was conducted by using primarily "worst case" assumptions. Assumptions used include:

- the total of NSPS control costs were incremental costs; i.e., that there are no SIP control costs that a plant would have to incur in the absence of NSPS control.
- the production volume is constant through the life of the project except for the crushed stone plant where it is assumed that they operate at 50% of capacity for the first year.
- NSPS control cost pass through is limited by competition of existing plants in the same industry which do not have to meet the NSPS standard.
- the new plant operates as a separate business entity and cannot expect to finance the control from another business activity or parent firm.

For new plants Table 8.40 shows that the 9 and 23 Mg/hr (10 and 25 tph) plants in sand and gravel, and crushed stone, and the 9 Mg/hr (10 tph) plants in common clay and pumice are likely to be significantly impacted by the NSPS. The DCF model was not able to determine a clear positive or negative investment decision for the 9 Mg/hr (10 tph) gypsum, 23 Mg/hr (25 tph) clay and 68 Mg/hr (75 tph) pumice, sand and gravel and crushed stone plant sizes. However, in view of the conservative assumptions used, they were judged to be economically feasible. All of the other plant sizes in the six industries are likely to be economically feasible after the promulgation of NSPS.

Table 8.41 shows that the DCF analysis produced an economically feasible result for all expansion size plants except for the 4.5 Mg/hr (5 tph) common clay plant where the investment decision result was unclear. However, in view of the conservative assumptions used, it was judged to be economically feasible.

For the 12 industries for which a DCF was not performed new plant construction would be feasible for all plant sizes because the greatest potential NSPS control cost absorption is equal to or less than 2% of the product price. Furthermore, for the other minerals where the potential control cost absorption was greater than 2% the DCF analysis produced an economically feasible result.*

New regulations shall be considered a major action if "additional annualized cost of compliance, including capital charges (interest and depreciation), will total $100 million (i) within any one of the first 5 years of implementation, or (ii) if applicable, within any calendar year up to the date by which the law requires attainment of the relevant pollution standard," or "the total additional cost of production of any major industry product or service will exceed 5% of the selling price of the product." Total industry annualized control costs in the fifth year after promulgation of NSPS and control costs as a percent of selling price are lower than the guidelines set for these measures of $100 million and 5%, respectively. Consequently, the proposed standards for the non-metallic minerals processing industry would be considered a routine action and not a major one.

---

*The portable crushing plant segments of the crushed stone, and sand and gravel industries are discussed in Supplement A.

8.1 UNITED STATES NON-METALLIC MINERALS INDUSTRY STRUCTURE

8.1.0.1 Introduction

The non-metallic minerals are numerous and range from such bulk commodities as sand and gravel and stone, the annual domestic demand for which is quoted in billions of short tons, down to industrial diamonds and gem stones, which are measured in carats. The last three decades of this century will be a period of rapid growth for the non-metallic mineral industries. The requirements for new buildings, road construction, rehabilitation of blighted cities, food production, chemical manufacture, ceramics, metal working, and the host of other established uses of non-metals can be expected to increase in volume. Of equal long-term significance are the opportunities to supplement and replace metals as they become scarce and expensive. Development of performance specifications will expand the use of composites of metals, non-metals, and non-mineral materials in new and improved end products. Research leading to significant improvements in the properties of the abundantly available non-metals also will enhance their utility.

The domestic non-metallic mineral industries, with a few exceptions, should be able to provide adequate supplies from domestic sources at reasonable costs to the year 2000. For the exceptions, supplies can be obtained from foreign sources or alternatives such as substitutes. However, the maintenance of a high degree of domestic self-sufficiency will require solution of many technical and economic problems. For some commodities, such as kyanite, synthesis from domestic raw materials offers a feasible solution to supply problems. Increased recovery of by-products, improvement of technology enabling use of lower grade reserves, and improvements in production and transportation facilities and costs are other means of enhancing the domestic supply position.

Serving, as non-metallics do, extremely heterogeneous markets, there is less tendency toward vertical and horizontal integration than in some of the metallic and fuel categories. However, there are advantages of scale and organization to be gained in some of the larger industries so there has been some consolidation among producers serving the construction and fertilizer fields. Continuation of this trend may be expected where efficiency benefits can be achieved.

--Warren E. Morrison and Robert E. Johnson, Jr., from Mineral Facts and Problems: 1970 Edition.

The industry structures which follow for the 18 non-metallic minerals being considered here have been prepared to provide background information to assist in the development of atmospheric emission limits under Federal New Source Performance Standards (NSPS) for industry processes.

In order to maintain as high a degree of consistency as possible for non-metallic minerals considered here across the years 1972-1976, statistical and analytical data presented is derived or cited from U.S. Bureau of Mines documents in most every instance and supplemented with significant data from other sources when necessary.

Each of the individual industry structures is based on the general outline that follows:

INDUSTRY STRUCTURE

1. General

   Mineral(s) description coverage of the analysis

2. Plants-define

   - number and employment
   - size
   - geographic distribution

3. Companies

   - number
   - concentration

4. Industry Statistics

   - Production
   - Consumption
   - Prices
   - Imports
   - Exports
   - Stocks
   - Employees

All items of information noted in the outline are not available for some individual industries.

The 18 non-metallic minerals being considered here have been grouped into three classifications by end-use. In order of group production volume, they are as follows:

8.1.1 - Non-Metallic Minerals for Construction and Industrial Uses

8.1.1.1 Sand and Gravel
8.1.1.2 Crushed Stone
8.1.1.3 Gypsum
8.1.1.4 Diatomite
8.1.1.5 Perlite
8.1.1.6 Pumice
8.1.1.7 Vermiculite
8.1.1.8 Mica
8.1.1.9 Gilsonite

8.1.2 - Non-Metallic Minerals for the Chemical and Fertilizer Industries

- 8.1.2.1 Barite
- 8.1.2.2 Fluorspar
- 8.1.2.3 Salt
- 8.1.2.4 Boron
- 8.1.2.5 Sodium Compounds

8.1.3 - Non-Metallic Minerals for Clay, Ceramic and Refractory Industries

- 8.1.3.1 Clays
- 8.1.3.2 Feldspar
- 8.1.3.3 Kyanite
- 8.1.3.4 Talc

Each section includes a summary table illustrating salient industry statistics estimates for 1976 obtained from the U.S. Bureau of Mines Commodity Data Summaries Annual for 1977. In some cases 1975 and 1976 data is not yet available and more complete data from former years has been used.

8.1.1 NON-METALLIC MINERALS FOR CONSTRUCTION AND INDUSTRIAL USES

8.1.1.1 Sand and Gravel

Sand and gravel has been, and will continue to be, the principal construction material in the United States. It exceeds the use of crushed stone in construction by about 222 million Mg or 245 million short tons (1974). Sand and gravel has the lowest average unit value of all mineral commodities, and it is one of the fastest growing mineral producing industries in the United States.

8.1.1.1.2 U.S. Plants

In 1976, there were an estimated 7,000 sand and gravel operations. The individual sand and gravel operations range in size from those producing over 3.6 million Mg (4 million tons) annually to those reporting production less than 4335 Mg (5,000 tons). In 1974, 23 percent of total production was from 89 operations producing .9 million Mg (1 million tons) or more, but 58 percent was produced by 6,604 operations in the range from 45,350 to 453,500 Mg (50,000 to 500,000 tons) per year.

The sand and gravel industry is highly mechanized and employs an estimated 50,000 men. About 90 percent are production workers and the balance are clerical, maintenance, and other staff personnel.

Output of sand and gravel has grown at a faster rate than employment for the past two decades, reflecting an increase in productivity. Average output has almost doubled from 4.08 Mg (4.5 tons) per man-hour in 1949 to nearly 8.2 Mg (9 tons) per man-hour in 1973. This increase in productivity has to date been adequate to compensate for the increasing hourly cost of labor and higher costs for equipment, land acquisition, rehabilitation and other factors related to production.

Because of its low unit value it is necessary to produce sand and gravel near the point of use; therefore, geographically the sand and gravel industry is concentrated in the large, rapidly expanding urban areas and, on a transitory basis, in areas where highways, dams, and other large-scale public and private works are under construction. The largest operations tend to be concentrated in States with the largest total production, yet production of sand and gravel is so widespread many firms and plants are involved.

In 1974, of 89 sand and gravel operations with an annual production of .9 million Mg (one million tons) or more, 18 were located in California.

8.1.1.1.3 U.S. Companies

Sand and gravel operations were owned by 4,700 companies in 1976. Producers may be large or small, public or private, turning out one product or a range of products, sell bank-run material or subject their material to processing. The average company produces 220 Mg/hr (250 TPH).

8.1.1.1.4 U.S. Production, Consumption and Prices

Production of common varieties of sand and gravel is tied very closely to activity in the consuming industries, principally construction of all general types. Production of special qualities of sand is associated chiefly with the needs of the glass industry and foundries. Sand and gravel production, consumption and other industry statistics are presented in Table 8-1.

Table 8-1 SAND AND GRAVEL: SALIENT STATISTICS

Salient Statistics--United States	1972	1973	1974	1975	1976e/
Production	829,292 (914,324)	892,152 (983,629)	820,514 (904,646)	716,015 (789,432)	698,390 (770,000)
Imports	690 (761)	725 (800)	357 (394)	339 (374)	226 (250)
Exports	1,651 (1,821)	1,581 (1,744)	2,046 (2,256)	2,919 (3,219)	3,265 (3,600)
Apparent consumption	828,330 (913,264)	891,295 (982,685)	818,825 (902,784)	713,434 (786,587)	695,331 (766,650)
Price $/Mg (dollars per ton)	1.52 (1.38)	1.52 (1.38)	1.73 (1.57)	1.97 (1.79)	2.18 (1.98)
Stocks, year end	Not available				
Employment: Mine e/	43,000	49,000	39,000	36,000	34,000

Source: Commodity Data Summaries Annual, 1977, U.S. Bureau of Mines)

The highway and general building construction industries are the greatest consumers of sand and gravel. As such, construction activity virtually determines the demand and supply of sand and gravel for any given period. During 1976, approximately 97 percent of the total U.S. sand and gravel output was used in the construction industries.

Construction will continue to dominate the end-use picture for sand and gravel. Industrial sand and gravel, although important, will constitute only a small percentage of the total volume of domestic sand and gravel requirements.

Labor, energy (electricity, fuel oil, and gasoline), and water are the major requirements for the production of marketable sand and gravel products. Actual operating costs for production are variable. Production costs vary widely depending upon geographic location and composition of deposits. The portable plant segment of the sand and gravel industry is discussed in Supplement A.

8.1.1.2 Crushed Stone

8.1.1.2.1 General

Crushed stone is a term used to describe a rock which has been reduced in size after mining to meet various consumer requirements. The rock may meet any one of many minerological definitions, including limestone, granite, trap rock, and others. The stone industry is the largest non-fuel, non-metallic mineral industry in the United States from the standpoint of total value of production and is second only to sand and gravel in volume produced.

8.1.1.2.2 U.S. Plants

There are currently 5,400 crushed stone quarries in the United States as reported by the Bureau of Mines. Of these, approximately 2,300 are considered by the Bureau of the Census (SIC's 1422, 1423, and 1429) to be commercial operations primarily concerned with the production of crushed stone. The remaining 3,100 consist of quarries operated by federal, state, and local governments, quarries that are part of integrated (cement, lime, etc.) operations, quarries operated on a temporary basis by establishments not concerned primarily with the production of stone (e.g., highway contractors, SIC 1611), and small quarries operated without paid employees but proprietor-operated. Some of these latter categories enter and re-enter the market. The 5,400 quarries are served by approximately 4,000 plants.

Included in the Bureau of Mines data, but not in the Census data, are portable crushing plants. These plants, which number 1,700, constitute a good portion of those plants referred to above which are attached to either the federal government or highway contractors, and which may enter or re-enter the market on an irregular basis. They also service small quarries in rural areas for a short period each year, sufficient to crush and stockpile a community's immediate needs. The portable plant segment of the crushed stone industry is discussed in Supplement A.

8.1.1.2.3 U.S. Companies

The crushed stone industry is comprised of a large number of small, locally owned firms which account for a minor proportion of national production, and a small number of larger firms which are regionally or nationally diversified, and account for a large percentage of the national production.

Patterns of firm ownership are similar to those in other sectors of the construction-oriented basic materials industries. At one extreme there are the small local operations, often operated as proprietorships, where the plant manager and the owner are one and the same person. At the other extreme are the plants owned by major firms for whom the crushed stone business is but one part of a number of fields of enterprise. Plant managers for these firms rarely have an equity interest in the firm for which they work, being regular employees whose tenure at a particular quarry may be temporary in nature.

In 1976 crushed stone was produced by 2,000 companies at 5,400 quarries in 49 states for dense graded roadbase stone, concrete aggregate, roadstone, cement, bituminous aggregate, and other uses. Leading states were Illinois, Pennsylvania, Texas, Missouri, and Ohio, which accounted for 30% of the total production. Output decreased 1% to 806 million Mg (888 million tons) valued at $2.02 billion. Of the total, 74% was limestone, 10% was granite, and 9% was traprock.

8.1.1.2.4 U.S. Production, Consumption, Prices

Salient industry statistics are presented in Table 8-2.

Table 8-2 U.S. CRUSHED STONE INDUSTRY (in thousand Mg and thousand short tons in parentheses)

	1972	1973	1974	1975	1976 e/
Production	835 (920)	962 (1,060)	946 (1,043)	819 (903)	807 (890)
Imports for consumption	4 (4)	4 (4)	4 (4)	4 (4)	4 (4)
Exports	2 (2)	3 (3)	3 (4)	3 (4)	3 (4)
Apparent consumption	836 (922)	962 (1,061)	946 (1,043)	819 (903)	807 (890)
Average price:					
Crushed stone	$1.88 ($1.72)	$1.97 ($1.80)	$2.19 ($2.00)	$2.57 ($2.35)	$2.61 ($2.39)
Stocks, year-end		Not	Available		
Employment Quarry & mill e/	64,000	64,000	64,000	55,000	54,000

Source: Commodity Data Summaries Annual, 1977, U.S. Bureau of Mines.

End Uses

The end uses for crushed stone are many and varied but construction and construction-related applications account for at least 80% of total shipments. Crushed stone is either used directly in its natural state or is shipped for further processing into miscellaneous manufactured products.

In its natural state, stone is an important ingredient for highway and street construction where it can form the base of the road, be included in the concrete or bituminous pavement as an aggregate or be used as an anti-skid material for surface treatment. As an aggregate in other types of concrete, stone is sold to ready-mix and precast concrete manufacturers as a basic ingredient for structural concrete.

Future Growth

The long-term historic rate of growth (1963-1972) for crushed stone has been at an annual rate of 3.3%. This rate of growth will probably modify somewhat over the remainder of the decade, partly because the rate of construction expenditures will reduce from 2.1% over the same period to no more than 2.0% from 1972 to 1980, but also because the industry has reached a stage of mature stability with respect to product substitutions. The rate of construction growth will be slower due to a combination of inflationary, energy and recessionary factors impacting business and individuals, as well as the fact that base year 1972 was a strong one for construction activity. We thus anticipate that crushed stone consumption will grow at about 3% per year compounded to 1980 from 1974 on a tonnage basis. Limestone and granite will both increase their current proportion of total crushed stone consumption and grow at slightly faster rates than the average. Little or no growth is anticipated in the consumption of traprock or sandstone, while miscellaneous stone types will continue to decrease in total tonnage.

Possibilities of Substitution

Limited substitution of alternative products can and does occur depending on the geographic location of an operation. Sand and gravel, blast furnace slag, and lightweight aggregates can be used interchangeably with crushed stone and many specifications accept or even encourage substitutions. An important criterion considered in making such a decision are the relative distances of available materials sources from the user. Thus, sand and gravel pits may prove to be favored as concrete aggregates if the geology and extraction location shows them to be more economic than stone quarries. Blast furnace slag, readily available where steel mills are located, can often be an economic source of aggregate and can also offer distinct performance advantages when used as an antiskid highway surfacing material. Lightweight aggregates, such as expanded shale or clay, perlite, or vermiculite can result in considerable reductions in concrete density, and thus building load, when substituted for crushed stone, but the economic availability of these aggregates is limited.

Marketing and Distribution

Distribution of crushed stone is direct from the quarry to the end user with no intermediary involved. Inventories are held almost entirely at the quarry location, as double handling would be prohibitively expensive, and customers maintain only sufficient inventory to insure uniform production rates over a predetermined length of time. Crushed stone production and shipments is a very seasonal business in many northern regions. Producers there will typically operate their plants for nine months a year and stockpile sufficient stone to cover a greatly reduced rate of shipments in the winter months.

Price Elasticity and Pricing Dynamics

On an industry basis, the demand for crushed stone is price inelastic. As the product is a necessary component of a number of building materials (concrete, asphalt) and products (roads, airport runways, etc.), its demand is based primarily on the demands for these products irrespective of its price. The fact that there generally does not exist significant competition from substitute products, and the price of stone as a percentage of the total price of the materials and products of which it is a component is low (15% of the FOB price of asphalt--less than 1% of the price of a highway for which the asphalt is being supplied, for example), variations in the price of crushed stone will not affect basic demand.

On a plant-by-plant basis, however, price competition is severe. The crushed stone business is highly capital-intensive, and producers need to maintain production volume to provide for the amortization of their capital investments. Thus, while the industry may be tending to an oligopoly in the local areas where business is transacted, the oligopoly is extremely competitive in a business sense with regards to price.

8.1.1.3 Gypsum

8.1.1.3.1 General

Anhydrite and selenite usually occur together, but calcined gypsum is a manufactured product never found in nature. Calcined gypsum is produced by heating selenite at about 350°F for over an hour. When water is added to calcined gypsum, plaster of paris is formed, which quickly sets and hardens to selenite again. All of these products, including the articles molded from the plaster, are called gypsum.

8.1.1.3.2 U.S. Plants

In 1973, there were 76 plants calcining gypsum in the U.S. with individual yearly production falling between 9,070 - 453,500 Mg (10,000 - 500,000 tons) per year.

In the United States, production of crude gypsum is centered around three general areas, the Great Lakes area, Texas-Oklahoma, and California. Leading States were Michigan, California, Texas, Iowa, and Oklahoma. These five States accounted for 60 percent of the total output.

8.1.1.3.3 U.S. Companies

The domestic gypsum industry is a large, well-integrated industry, in which a few large companies are prominent. These companies mine and sell crude gypsum for use in cement or agriculture. They mine and import crude gypsum, calcine it, and market gypsum products. Leading mining companies were U.S. Gypsum Co. (13 mines), National Gypsum Company (8 mines), Georgia-Pacific Corporation (7 mines), the Flintkote Company (3 mines), and H. M. Holloway, Inc. (1 mine). These five companies accounted for 73 percent of the total output of crude gypsum. Thirty-four smaller companies operated 37 mines.

8.1.1.3.4 U.S. Production, Consumption, Prices

Salient industry statistics are presented in Table 8-3.

Table 8-3 U.S. GYPSUM INDUSTRY (thousand Mg and thousand short tons in parentheses)

	1972	1973	1974	1975	1976 e/
Production: Crude	11,181 (12,328)	12,297 (13,558)	10,883 (11,999)	8,844 (9,751)	10,430 (11,500)
Calcined	10,888 (12,005)	11,420 (12,592)	9,970 (10,993)	8,327 (9,181)	9,432 (10,400)
Imports: Crude, including anhydrite	7,000 (7,718)	6,948 (7,661)	6,733 (7,424)	4,941 (5,448)	6,049 (6,670)
Exports: Crude, crushed or calcined	46 (51)	57 (63)	119 (132)	68 (75)	68 (75)
Consumption: Crude, apparent	18,135 (19,995)	19,188 (21,156)	17,496 (19,291)	13,717 (15,124)	16,384 (18,095)
Value: Average crude (f.o.b. mine) $/Mg (per ton)	$4.33 ($3.93)	$4.61 ($4.18)	$4.86 ($4.41)	$5.05 ($4.58)	$5.29 ($4.80)
Average calcine (f.o.b. plant) $/Mg (per ton)	$18.00 ($16.32)	$17.98 ($16.31)	$20.63 ($18.71)	$22.40 ($20.31)	$23.47 ($21.28)
Stocks: Producer, crude, yearend e/	3,909 (4,310)	3,628 (4,000)	2,721 (3,000)	1,814 (2,000)	1,360 (1,500)
Employment: Mine and calcining plant	4,200	4,500	4,800	5,000	5,100

Source: Commodity Data Summaries Annual, 1977, U.S. Bureau of Mines.

End Uses - Crude gypsum is marketed for use in cement, agriculture, or fillers. In portland cement, gypsum is universally used to retard the setting of the concrete. In agriculture, gypsum is used to neutralize alkaline soils and to provide sulfur.

Calcined gypsum is marketed as plaster or prefabricated products. Building plaster is generally reground, and retarder and binders are added. Retarder is usually a glue-type material made from meatpacking-plant by-products.

The U.S. is the leading world producer and consumer of gypsum with 18 percent of production and 28 percent of consumption. The United States is a net importer of gypsum.

Gypsum is a low-cost, high tonnage commodity that must compete with many other building materials. Large mines and integrated plants have helped producers remain competitive.

8.1.1.4 Diatomite

8.1.1.4.1 General

Diatomite in its natural state is a soft rocklike material consisting mainly of an accumulation of siliceous frustules (shells) or skeletons of diatoms that are microscopic single-celled plants of freshwater and saltwater origin. Chemically, diatomite is essentially amorphous hydrated or opaline silica with varying amounts of contaminants such as silica sand, clay minerals, metal salts, and organic matter.

8.1.1.4.2 U.S. Companies/Plants

The United States is the world's largest producer and consumer of diatomite. In 1976, 9 companies actively mined and prepared diatomite from 16 operations in 5 states--California, Kansas, Nevada, Oregon, and Washington.

The major firms have other mineral and manufacturing interests such as the production of asbestos products, roofing, floor tile, acoustic insulation, refractories, lead and zinc, plastics, thermal insulation, chemicals, and industrial fillers.

Employment in the diatomite mining and processing sectors of the industry is estimated to be about 900 employees.

8.1.1.4.3 U.S. Production, Consumption, and Prices

Salient industry statistics for the diatomite industry are presented in Table 8-4:

Table 8-4. U.S. DIATOMITE INDUSTRY (in thousand Mg and thousand short tons in parentheses)

Production: Mine	1972	1973	1974	1975	1976 e/
Imports, general	522 (576)	552 (609)	602 (664)	519 (573)	563 (621)
Exports	(1/)*	(1/)	(4) 3	(4) 3	(5) 4
Apparent consumption	134 (148)	161 (178)	168 (186)	133 (147)	140 (155)
Price $/Mg (average per short ton)	390 (430)	392 (433)	437 (482)	390 (430)	427 (471)
Stocks, yearend e/	$71.90 (65.19)	$65.36 ($59.26)	$84.16 ($76.31)	$88.25 ($80.01)	$97.83 ($88.70)
Employment: Mine and plant e/	34 (38) 800	32 (36) 850	32 (36) 875	32 (36) 900	32 (36) 900

---

*Less than 100 mg

Source: Commodity Data Summaries Annual, 1977, U.S. Bureau of Mines.

The United States is the largest producer and exporter of diatomite. Exports have risen very gradually from 116,096 Mg (128,000 short tons) in 1964 to 168,702 Mg (186,000 tons) in 1974.

The principal diatomite-producing countries are also the major exporters of diatomite products. Diatomite is used in nearly every country primarily for filtration purposes.

Domestic use for diatomite as a filter medium comprised 53 percent of the 433,546 Mg (478,000 tons) consumed in 1974.

The quantity of processed diatomite used as a filler or extender in the preparation of various industrial chemicals and paints in the United States in 1974 was 99,770 Mg (110,000 tons), 23 percent of total consumption.

Transportation has always been an important cost factor in the price of diatomite to the ultimate consumer because the product is a high-bulk commodity, and thus has a high freight rate per ton. The cost of moving diatomite (bulk shipments) from western producing points to midwestern and east coast markets, for example, has ranged from $27 to $38/Mg ($25 to $35 per ton). However, because of essential industry applications for diatomite, transportation costs have not seriously affected supply and demand in the past.

8.1.1.5 Perlite

8.1.1.5.1 General

Perlite, a glassy volcanic rock, has the unusual characteristic of expanding to about 20 times its original volume when heated to an appropriate temperature within its softening range. The resultant expanded product finds a variety of industrial and constructional applications owing to the material's low density with attendant properties of low thermal conductivity and high sound absorption.

8.1.1.5.2 U.S. Companies/Plants

Domestic production of crude perlite (quantity sold and used) in 1976 was a record 598,620 Mg (660,000 tons) from 11 operations in 6 Western States. Deposits in New Mexico supplied 88 percent of the total crude perlite mined in 1974. Expanded perlite was produced at 76 plants in 30 States. The principal States in descending order of expanded perlite output in 1974 were Illinois, Mississippi, Kentucky, Pennsylvania, Colorado, Florida, New Jersey, Texas, California, and Indiana.

Employment in perlite mining and milling was estimated to be 121 employees in 1976. In addition, there were many hundred more employees in the expanding, product development, basic research, and marketing activities of the industry.

8.1.1.5.3 U.S. Production, Consumption, and Prices

Salient industry statistics for the domestic perlite industry are presented in Table 8-5.

Table 8-5. U.S. PERLITE INDUSTRY (in thousand Mg and thousand short tons in parentheses)

Salient Statistics--United States:	1972	1973	1974	1975	1976 e/
Production: Mine	588 (649)	688 (759)	613 (676)	640 (706)	598 (660)
Imports	None of Record				
Exports	Not Available				
Consumption, reported	494 (545)	493 (544)	503 (555)	464 (512)	491 (542)
Price (sold to expanders): $/Mg (Per ton), f.o.b. mine	$12.50 ($11.34)	$12.83 ($11.64)	$14.21 ($12.89)	$15.72 ($14.26)	$17.35 ($15.73)
Stocks, year-end	Not Available				
Employment: Mine and mill	100	100	110	110	121

Source: Commodity Data Summaries Annual, 1977, U.S. Bureau of Mines.

Industrial uses for perlite (expanded) are many and varied. The more important applications include the following: abrasives, acoustical plaster and tile, charcoal barbecue base, cleanser base, concrete construction aggregates, filter aid, fertilizer extender, foundry ladle covering and sand additive, inert carrier, insulation board filler, loosefill insulation, molding filler medium, packaging medium, paint texturizer, pipe insulator, plaster aggregate and texturizer, propagating cuttings for plants, refractory products, soil conditioner, tile mortar aggregate and lightweight insulating concrete for roof-decks, and wallboard core filler.

Exfoliated vermiculite is the most directly competitive material with perlite aggregates in plaster and other insulation applications in the construction field. Lightweight aggregates such as pumice, expanded clay, shale, and slag, volcanic cinders, or foamed concrete are used where considerations of lower cost or greater structural strength more than balance the advantage of low density achieved by using perlite.

8.1.1.6 Pumice

8.1.1.6.1 General

Although domestic use prior to World War II was largely as an abrasive, the importance of pumiceous materials as low-cost construction aggregate increased rapidly and has since dominated the U.S. pumice consumption pattern.

8.1.1.6.2 U.S. Plants

Domestic production of pumiceous materials in 1976 was 4.03 million tons from 235 operations in 12 States (including Hawaii) and American Samoa. The principal producing States are Arizona, California, and Oregon, and their combined output accounted for 68 percent of the national total of pumiceous materials in 1974. Other States with significant output were Hawaii, Nevada, and New Mexico.

Although employment in the pumiceous materials industry varies considerably from year to year, owing primarily to closing and opening of volcanic cinder pits when local contracts for road construction material terminate and start up, it was estimated that about 600 workers were in mining and processing in 1976.

8.1.1.6.3 U.S. Companies

In 1976 there were 77 pumice producing companies. Producers range from private individuals to companies to governmental agencies at local, State and Federal levels. There is also a wide range from small, intermittent, to large tonnage operations. Most of the producers have mining and processing of pumiceous materials as their sole or major interest; however, some, such as railroad companies and road construction contractors, produce the material only as a subsidiary part of their principal business.

8.1.1.6.4 U.S. Production, Consumption and Price

Industry statistics for the domestic supplier industry is presented in Table 8-6.

Table 8-6. U.S. PUMICE INDUSTRY (in thousand Mg and thousand short tons in parentheses)

	1972	1973	1974	1975	1976 e/
Production: Mine	3,458 (3,813)	3,570 (3,937)	3,570 (3,937)	3,530 (3,892)	3,655 (4,030)
Imports for consumption	543 (599)	281 (310)	265 (293)	131 (145)	73 (81)
Exports	(1/)*	2 (3)	2 (3)	(1/)	(1/)
Apparent consumption	4,002 (4,413)	3,849 (4,244)	3,833 (4,227)	3,660 (4,036)	3,727 (4,110)
Price: $/Mg (per ton), f.o.b. mine or mill (avg.)	$1.88 ($1.71)	$2.49 ($2.26)	$2.55 ($2.32)	$3.17 ($2.88)	$3.32 ($3.01)
Stocks, year-end	Not Available				
Employment: Mine and mill	525	545	560	580	600

---

* less than 1000 Mg.

Source: Commodity Data Summaries Annual, 1977, U.S. Bureau of Mines.

The largest domestic use of pumiceous materials is in the construction industry, which accounted for 92.5 percent or 3 million Mg (3.9 million tons) of demand in 1974. Construction uses principally include road surfacing, maintenance, and ice control, concrete admixtures and aggregate, and railroad ballast. Demand for other uses totaled 263,030 Mg (290,000 tons) in 1974; the quantity of pumice used only for various abrasive purposes was estimated to be 22,675 Mg (25,000 tons).

Transportation is an important cost factor in the economics of the domestic pumice industry. Abrasive grades ($34.00/Mg - $31.00/ton) can be shipped even from foreign sources and be competitive; but pumice of low market value ($1.13/Mg - $40/ton) such as that used for construction purposes, is usually limited to a few hundred miles by rail or truck transportation. Pumice for construction uses becomes less competitive with alternate choice materials in rough proportion to the distance that pumice resources are available from the place of consumption.

8.1.1.7 Vermiculite

8.1.1.7.1 General

Vermiculite, a mica-like mineral with the unique property of exfoliating to a low-density, bulky material when heated, is widely used in the construction industry. Vermiculite concrete is used for roof decks and floor fill where lightweight, thermal insulation, and acoustical properties are of particular importance.

8.1.1.7.2 U.S. Companies/Plants

In 1975, the only domestic producers of crude vermiculite were the Construction Products Division, W. R. Grace & Company, which operates a large mine near Libby, Montana, and a group of smaller mines near Enoree, South Carolina, and Patterson Vermiculite Company, Enoree, South Carolina.

Exfoliated vermiculite was produced at 53 plants in 31 States in 1974. Five States supplied 46 percent of the total: California, Florida, New Jersey, South Carolina, and Texas. W. R. Grace & Company, the leading producer of crude vermiculite, operated 28 exfoliating plants. Patterson Vermiculite Company used all its production of crude vermiculite at its Enoree, South Carolina exfoliating plant. Twenty-two other firms operated 25 exfoliating plants. W. R. Grace & Company had a financial interest in several of these firms, but most of them were independent processors. Total production of crude and exfoliated vermiculite in 1974 was 309,287 and 249,425 Mg (341,000 and 275,000 short tons), respectively.

Most exfoliating plants are small, and over half produce less than 4535 Mg (5,000 tons) each of expanded vermiculite annually. About 250 workers were employed at vermiculite mines and mills in 1973. Several hundred additional employees operated vermiculite exfoliating plants.

8.1.1.7.3 U.S. Production, Consumption, and Prices

Industry statistics for vermiculite are presented in the following table.

Table 8-7. U.S. VERMICULITE INDUSTRY (in thousand Mg and thousand short tons in parentheses)

Salient Statistics--United States:	1972	1973	1974	1975	1976
Production: Mine	305 (337)	331 (365)	309 (341)	299 (330)	272 (300)
Imports: Crude	23 (26)	27 (30)	38 (42)	29 (33)	27 (30)
Exports:	NA	NA	NA	38 (42)	40 (45)
Consumption: Exfoliated	224 (247)	265 (293)	249 (275)	213 (235)	204 (225)
Prices: Average $/Mg (per ton), f.o.b. mine	$26.48 ($24.01)	$28.60 ($25.93)	$32.73 ($29.68)	$46.06 ($41.76)	$46.32 ($42.00)
Producer stocks, year end	Not Available				
Employment: Mine and mill	225	250	250	250	250

Source: Commodity Data Summaries Annual, 1977, U.S. Bureau of Mines.

Railroad freight rates are high, and shipping costs for crude vermiculite sometimes exceed the mine value. The rail-freight rate for shipping vermiculite from Montana to the Atlantic and Gulf coasts is comparable with the transportation cost from South Africa. This makes it economic for some South African crude to enter the country. Some of this vermiculite is transshipped by rail or barge to inland points.

8.1.1.8 Mica

8.1.1.8.1 General

Mica is a group name for a number of complex, hydrous potassium silicate minerals with differing chemical composition and physical properties. Crystals of mica have characteristic excellent basal cleavage and split easily into tough, flexible sheets. Principal minerals of this group are muscovite (potassium mica), phlogopite (magnesium mica), biotite (magnesium iron mica) and lepidolite (lithium mica). Muscovite and phlogopite are the most important commercial micas.

8.1.1.8.2 U.S. Companies/Plants

In 1974, block and film mica was produced by 13 companies in 7 States. New Jersey with four consuming plants, New York with three, North Carolina with two, and Pennsylvania with one produced 75 percent of the domestically fabricated block and film. Other States with block and film fabricators are Massachusetts, Ohio, and Virginia.

Splittings were fabricated into various built-up mica products by 11 companies with 12 plants in eight States. Plants in New Hampshire, New York, and Ohio consumed 80 percent of the splittings. Other States with plants consuming mica splittings were Michigan, Massachusetts, North Carolina and Virginia.

North Carolina was the largest scrap and flake producing State with 56 percent of total production in 1974. The remaining output of scrap and flake mica came from Alabama, Arizona, Connecticut, Georgia, New Mexico, South Carolina, and South Dakota.

Ground mica was produced by 16 companies with 18 plants in the following 10 States: Alabama, Arizona, Georgia, Illinois, New Hampshire, New Mexico, North Carolina, Pennsylvania, South Carolina, and Texas.

8.1.1.8.3 U.S. Production, Consumption and Prices

Salient statistics for the U.S. mica industry are presented in the following table.

Table 8-8. U.S. MICA INDUSTRY (in thousand Mg and thousand short tons in parentheses)

	1972	1973	1974	1975	1976
Production: Mine	134 (148)	138 (153)	124 (137)	122 (135)	119 (132)
Imports for consumption	1	2 (3)	2 (3)	5 (6)	5 (6)
Exports e/	4 (5)	4 (5)	4 (5)	4 (5)	4 (5)
Consumption	117 (130)	124 (137)	106 (117)	102 (113)	104 (115)
Price per Mg (avg. per ton):					
Scrap & flake	$30.01 (27.21)	$30.01 ($27.21)	$37.89 ($34.36)	$42.64 ($38.66)	$44.12 ($40.00)
Ground (current year)	Dry: $44-110 ($40-100/ton) Wet: $242-397 ($220-360/ton)				
Stocks: Consumer, yearend e/	25 (28)	20 (23)	30 (34)	47 (52)	45 (50)
Employment: Mine e/	68 (75)	68 (75)	58 (65)	54 (60)	54 (60)

Source: Commodity Data Summaries Annual, 1977, U.S. Bureau of Mines.

Demand for ground mica is linked primarily to the building industry; however, 1973 was a record high year for both ground and scrap and flake mica. The production of ground and scrap and flake mica was significantly lower for 1974 and 1975 because of problems in the building industries.

In 1974, ground mica for use in gypsum wallboard cement required 37,187 Mg (41,000 short tons), followed by paint with 30,838 Mg (34,000 short tons), roofing materials with 9,070 Mg (10,000 short tons), and the rubber industry with 6,349 Mg (7,000 short tons).

Many substitutes are available for ground mica when it is used as a filler. Ground synthetic fluorophlogopite has been successfully used to replace natural ground mica for uses that require the thermal properties of the mica.

8.1.1.9 Gilsonite

8.1.1.9.1 General

According to Mr. E. G. Williams, an Asphalt Institute Engineer stationed in Louisville, Kentucky, at present there is no production of natural rock asphalt in the United States. Production ceased about 1965 due to the exorbitant cost of the natural product compared to asphalt produced by petroleum cracking processes. There are no known plans to resume production of natural rock asphalt.

The American Gilsonite Company in Utah is the only domestic producer of metamorphosized asphalt called gilsonite. Production is less than 90,700 Mg (100,000 tons) per year used primarily for specialty products. Less than 9,070 Mg (10,000 tons) per year is consumed east of the Mississippi River.

E.G. Williams
Asphalt Institute Engineer
4050 Westport Road
Louisville, Kentucky 40207
(502) 895-6966

8.1.2 NON-METALLIC MINERALS FOR THE CHEMICAL AND FERTILIZER INDUSTRIES

8.1.2.1 Barite

8.1.2.1.1 General

Barite ($BaSO_4$) is the only source of barium and barium compounds. The term "primary barite," as used in this report, refers to the first marketable product and includes crude barite, flotation concentrate, and other beneficiated material such as washer, jig, or magnetic separation concentrate. Most primary barite requires fine grinding before it is used for drilling muds. This grinding may or may not be done at the mine site.

8.1.2.1.2 U.S. Plants/Companies

Domestic production of barium in 1976 was from 31 mines in 9 States. Nevada supplied 69 percent of the tonnage. Missouri produced 16 percent. Alaska, Arkansas, California, Georgia, Idaho, Illinois, and Tennessee were other producing States.

Companies which specialize in the drilling mud business also have foreign mines and import part of their barite supplies. They have grinding plants strategically located throughout the world to serve drilling mud markets. They provide a variety of drilling mud minerals, chemicals, and services to the oil and gas industry.

Ground and crushed barite was produced in 1974 mainly in Louisiana and Texas from domestic and imported material and in Arkansas, Missouri, and Nevada from domestic barite. Processing mills were also located in California, Georgia, Illinois, Tennessee, and Utah.

Domestic mining, milling, and grinding of barite to a marketable product required about 1200 employees in 1976. Most barite plants process from 9-45 Mg (10-50 tons) per hour.

8.1.2.1.3 U.S. Production, Consumption and Prices

Salient statistics for the U.S. barite industry are presented in the following table.

Table 8-9 U.S. BARITE INDUSTRY (in thousand Mg and thousand short tons in parentheses)

	1972	1973	1974	1975	1976 e/
Production: Mine 1/	821 (906)	1,101 (1,104)	1,103 (1,106)	1,167 (1,287)	1,024 (1,129)
Imports for consumption (crude barite)	565 (624)	649 (716)	661 (729)	575 (634)	680 (750)
Exports (ground and crushed)	47 (52)	61 (68)	55 (61)	51 (57)	42 (47)
Reported consumption (ground and crushed)	1,339 (1,477)	1,443 (1,592)	1,507 (1,662)	1,638 (1,807)	1,659 (1,830)
Price: $/Mg (per ton) f.o.b. mine (avg.)	$18.12 ($16.43)	$16.67 ($15.12)	$16.77 ($15.21)	$17.71 ($16.06)	$23.21 ($21.05)
Producer stocks, yearend	Not Available				
Employment: Mine and mill e/	1,025	1,100	1,200	1,200	1,200

Source: Commodity Data Summaries Annual, 1977, U.S. Bureau of Mines.

The United States is a net barite importer. Imports of barium in 1974 amounted to 40% of the total supply. Barium imports have remained near this percentage for the twenty-year trend.

The major use for barium is in the form of barite as a weighting material in well-drilling muds, accounting for 87 percent of the 1974 U.S. consumption.

Barite is also a raw material of chemical manufacturing. The major barium chemicals are the carbonate, chloride, oxide, hydroxide, nitrate, peroxide, and sulfate. The barium compounds represent 6 percent of total barium consumption.

A number of materials have been substituted for barite as a weighting medium in drilling muds in the past but never with a real competitive edge.

8.1.2.2 Fluorspar (Fluorine)

8.1.2.2.1 General

Fluorine, derived from the mineral fluorite, commonly known as fluorspar, is one of the most versatile and useful of the elements. Steadily increasing quantities are required in steel production, where the mineral fluorite is useful as a slag thinner; in aluminum production, where cryolite, another fluorine mineral, is necessary to dissolve alumina for the electrolytic cells; and in ceramics, where fluorite is a flux and opacifier. Strong as the fluorine demand has been in the foregoing uses, it has been even stronger for an important group of fluorocarbon chemicals which are formulated into refrigerants, plastics, solvents, aerosols, lubricants, coolants, surfactants, rocket fuels, medicinals, aluminum fluoride, and many other industrial products.

8.1.2.2.2 U.S. Plants/Companies

At the start of 1973, there were 23 mines and 7 froth flotation plants in operation; during the year 8 mines and 4 flotation plants closed down. Cumulatively over 126,980 Mg (140,000 tons) of flotation milling capacity was lost; but during the past 2 years the output from these plants has only averaged about 81,630 Mg (90,000 tons) annually, mainly because the mines could not supply the mills. In 1975, 10 companies operated 15 mines in the United States.

Although some domestic fluorspar is sold with little or no processing after mining, most crude ore requires beneficiation or yields a finished product.

Manpower required by the U.S. fluorspar industry is not large. An estimated 350 men are employed in mines and 250 in mills.

8.1.2.2.3 U.S. Production, Consumption, and Prices

Salient statistics for the U.S. fluorspar industry are presented in the following table. (Data in 1000 Mg; 1000 short tons in parentheses.)

Table 8-10. U.S FLUORSPAR INDUSTRY (in thousand Mg and thousand short tons in parentheses)

	1972	1973	1974	1975	1976[e]
Production: Finished (all grades)[1]	227 (251)	225 (225)	182 (182)	126 (140)	163 (180)
Fluorspar equivalent from phosphate rock	58 (65)	76 (84)	87 (97)	72 (80)	72 (80)
Imports for consumption: Acid-spar	644 (711)	640 (706)	764 *643)	633 (699)	535 (590)
Met-spar	427 (471)	458 (506)	447 (493)	318 (351)	261 (310)
Exports: Ceramic and acid grades	2 (3)	1 (2)	5 (6)	(1)	(1)
Sales of Gov't stockpile excesses	--	--	--	--	--
Apparent consumption	1349 (1488)	1368 (1509)	1296 (1429)	1179 (1300)	1060 (1169)
Reported consumption: Acid-spar	663 (731)	614 (677)	762 (841)	619 (683)	499 (550)
Met-spar	563 (621)	612 (675)	620 (684)	509 (562)	589 (650)
Price:[2] Acid-spar, $/Mg (per ton)	$93 ($85)	$93 ($85)	$99 ($99)	$106 ($97)	$116 ($106)
Met-spar, $/Mg (per ton)	$75 ($68)	$71 ($65)	$77 ($70)	$88 ($80)	$95 ($87)
Year-end stocks: Mine	13 (15)	8 (9)	12 (14)	9 (11)	10 (12)
Consumer	342 (376)	297 (328)	390 (431)	290 (320)	263 (290)
Employment: Mine[e]	600	600	350	300	300
Mill[e]	270	280	100	193	200

Source: Commodity Data Summaries Annual, 1977, U.S. Bureau of Mines.

[1] Shipments

Consumption of fluorine is chiefly in the chemical, steel, and aluminum industries. An estimated 622,202 Mg (686,000 tons) was consumed by U.S. industries in 1974. Mnay marginal U.S. mines have been forced to close owing to low-cost imports of fluorspar, contributing to greater dependence on foreign supply. A gradual upward trend in the price of foreign fluorine imports may result from increasing world demand and stimulate development of more reserves. Both domestic and foreign producers have instituted programs for increasing output by reopening and refurbishing existing mines and exploring for new deposits.

U.S. dependence on foreign supplies for most of its fluorine demand has existed since 1952 and is increasing. Lower foreign production cost rather than inadequate domestic deposits of fluorine minerals is the chief reason for the U.S. increasing dependence on foreign sources of supply.

8.1.2.3 Salt (NaCl)

8.1.2.3.1 General

Salt is an essential nutrient in the human diet and a major basic raw material for production of various chemicals and products. In 1974, about one-third of the world's salt was produced in Europe; another third in North America; and one-fifth in Asia. Vast salt reserves throughout the U.S. are concentrated in 16 states and estimated at 61 trillion tons.

8.1.2.3.2 U.S. Plants

In the United States there are 97 plants processing salt from 106 mines (1974). Most of these plants are concentrated in eight states which accounted for 96% of the total production of 1973. Louisiana and Texas are the major producer/processor states with 29.1 and 24.4 percent respectively of total 1974 U.S. production. U.S. employment in salt processing operations for 1976 was estimated to be 5,040.

8.1.2.3.3 Companies

There are 52 salt processing companies in the United States. In 1974, twelve companies each produced more than 1 million tons of salt accounting for 88% of total U.S. production. Eighteen companies individually producing between 90,700 - 907,000 Mg (100,000 and 1 million tons) added 11% to the total with the remaining 1% produced by 22 companies with a yearly output of less than 90,700 Mg (100,000 tons) each.

Most large salt companies are vertically integrated starting with salt produced as brine, for example, being consumed on the site for making chlorine and caustic soda or soda ash.

8.1.2.3.4 U.S. Production, Consumption and Process

Salient statistics for the U.S. salt industry are presented in the following table.

Table 8-11. U.S. SALT INDUSTRY (in thousand Mg and thousand short tons in parentheses)

	1972	1973	1974	1975	1976
Sold or used by producers 2/	40,834 (45,022)	39,826 (43,910)	42,208 (46,536)	37,214 (41,030)	38,127 (42,037)
Imports for consumption	3,140 (3,463)	2,908 (3,207)	3,045 (3,358)	2,916 (3,215)	3,741 (4,125)
Exports	788 (869)	552 (609)	472 (521)	1,208 (1,332)	946 (1,044)
Apparent consumption	43,187 (47,616)	42,182 (46,508)	44,781 (49,373)	38,922 (42,913)	40,922 (45,118)
Prices: Rock salt, medium course in 100 lb. bags, quoted dollars $/Mg (per ton)	$21.39 ($19.40)	$21.39 ($19.40)	$21.39 ($19.40)	$29.78 (27.00)	$29.78 (27.00)
Average sales price f.o.b. mine, dry (including bulk & pressed but excluding brine), $/Mg (per ton)	$11.71 ($10.62)	$12.97 ($11.76)	$14.12 ($12.81)	$15.91 ($14.43)	$18.29 ($16.59)
Stocks, yearend	NA	NA	4,700	2,400	2,400
Employment: Mine and Plant	5,070	4,950	5,280	4,920	5,040

Source: Commodity Data Summaries Annual, 1977, U.S. Bureau of Mines.

Percentage breakdowns for 1976 production end-uses roughly are: caustic soda and chlorine - 60%; synthetic soda ash - 11%; miscellaneous chemicals - 3%; highway deicing - 18%; salt for human consumption - 3%; and all other uses - 18%.

Because of its relatively low production cost and high bulk density, the cost of shipping salt is usually a large part of its cost as used. Such commodities are poorly suited to international trade. The 6.8% U.S. 1974 salt import was mainly from bordering Canada and Mexico.

8.1.2.4 Boron

8.1.2.4.1 General

— Boron is a versatile and useful element used mainly in the form of its many compounds, of which borax and boric acid are most well known. The largest single use of boron is in glassmaking where boron compounds add strength to the glass, especially above the temperatures of which ordinary glass softens.

While boron is not an extremely rare element, few commercially attractive deposits of boron minerals are known. It is estimated that about half of the commercially attractive world boron resources, estimated at about 72 million tons of boron, are in southern California.

8.1.2.4.2 U.S. Plants/Companies

Three companies produced borax in the United States during 1975, all operating in southern California. U.S. Borax & Chemical Corp., by far the most important producer, mined borax (or tincal) and kernite at a large open pit mine at Boron. U.S. Borax also owns and operates refineries and products plants at Boron in Kern County, at Wilmington in Los Angeles County, California, and at Burlington, Iowa.

Overall, nearly 2,000 persons are employed within the U.S. boron extraction industry. There is no secondary recovery and reuse of boron compounds, since almost all of this goes into dissipative uses.

8.1.2.4.3 U.S. Production, Consumption and Prices

Salient statistics for the U.S. boron industry are presented in Table 8.12.

Two-fifths or more of the boron compounds consumed were used in the manufacture of various kinds of glasses within the United States. Boron materials account for 5 to 10 percent of many special glasses by weight and 50 to 75 percent by value. About 15 percent of all boron consumed went into insulating fiberglass, 10 percent into textile fiberglass, and 15 to 20 percent into all other glasses. The energy shortage has created a further demand for insulating fiberglass.

Table 8.12 U.S. BORON INDUSTRY (in thousand Mg and thousand short tons in parentheses)

	1972	1973	1974	1975	1976
Production (boron minerals and compounds)	1,016 (1,121)	1,111 (1,225)	1,074 (1,185)	1,063 (1,172)	1,088 (1,200)
Imports (boron minerals and compounds	18 (20)	16 (18)	19 (21)	25 (28)	27 (30)
Exports (boric acid and refined borates)	172 (190)	190 (210)	230 (254)	223 (246)	235 (260)
Apparent consumption (contained boron)	NA	NA	103 (114)	88 (98)	95 (105)
Price: $/Mg (per ton)(granulated pentahydrate borax in bulk, f.o.b. mine)	$82 ($75)	$88 ($80)	$88 ($80)	$110 ($100)	$115 ($105)
Stocks, yearend	Not Available				
Employment 1/	1,800	1,800	1,800	1,800	1,900

Source: Commodity Data Summaries Annual, 1977, U.S. Bureau of Mines.

Between year-end 1973 and November 1974, the price of anhydrous borax (bulk) rose from 121/Mg ($110 per short ton) to $223/Mg ($203) for U.S. Borax, and the price of boric acid increased from $147 to 219/Mg ($134 to $199). These increases reflect steep rises in energy cost, inflation, and strong demand. The sharper rise in costs of anhydrous products, compared with costs of products with water, can be explained by the more intense use of energy in fusion than in distillation and chemical processing.

8.1.2.5 Sodium Compounds

8.1.2.5.1 General

— The compounds of sodium are of primary importance to the whole chemical manufacturing industry. Although not always present in the finished product, sodium plays some part in the preparation of nearly every product requiring chemical processing.

Soda ash is the term used in the industry for sodium carbonate.

Solvay soda or ammonia soda are terms used interchangeably for sodium — carbonate produced from salt by the Solvay process.

Salt cake is the term used for sodium sulfate. Glauber salt is a common hydrated form of sodium sulfate.

8.1.2.5.2 U.S. Plants

In 1975 there were nine soda ash plants, 4 synthetic and 5 natural, in the United States, located in New York, Michigan, Ohio, Texas, Wyoming and California. Sodium sulfate was produced at 28 plants in 15 states.

There were only four Solvay plants left in the United States in 1975 after the permanent closing of two major producers in Louisiana. High cost of fuel and other raw materials, combined with strict antipollution laws, have made it difficult for Solvay soda ash to compete with natural soda ash.

Most of the world's supply of natural soda ash comes from a small area in southwest Wyoming called the Freen River Basin. A secondary source of natural U.S. soda ash is in Searles Lake, California.

Natural sodium sulfate is extracted from brines of California, Texas, and Utah. About three-fourths of the by-product sodium sulfate plants are located east of the Mississippi River.

About 2,800 people are employed in the natural soda ash industry and an additional 130 in producing natural sodium sulfate.

8.1.2.5.3 U.S. Companies

There were eight soda ash companies in 1975; 4 synthetic and 4 natural; and three natural sodium sulfate companies. By-product sodium sulfate was produced by 18 companies in 15 states.

U.S. soda ash companies are: Kerr-McGee Chem. Corp., Stauffer Chemical Corp., Allied Chemical Corp., and FMC Corp.

U.S. sodium sulfate companies are: Stauffer Chemical Co., Kerr-McGee Chem. Corp., U.S. Borax & Chem. Corp., Ozark-Mahoning Co., and Great Salt Lake Minerals and Chem. Corp.

8.1.2.5.4 U.S. Production, Consumption and Prices

Salient statistics for the U.S. sodium carbonate industry are presented in the following table.

Table 8.13. · U.S. SODIUM CARBONATE INDUSTRY (in thousand Mg and thousand short tons in parentheses)

		1972	1973	1974	1975	1976 e/
Production:	Natural	2,918 (3,218)	3,375 (3,722)	3,681 (4,059)	3,925 (4,328)	4,699 (5,181)
	Manufactured (solvay)	3,904 (4,305)	3,458 (3,813)	3,180 (3,507)	2,541 (2,802)	2,193 (2,418)
Imports for consumption		--	14 (16)	31 (35)	2 (3)	1
Exports (mostly refined)		435 (480)	385 (425)	511 (564)	500 (552)	527 (582)
Apparent consumption (Nat. and synthetic)		6,388 (7,043)	6,463 (7,126)	6,382 (7,037)	5,968 (6,581)	6,365 (7,018)
Prices:	Soda ash, light, bulk, carlots, works, quoted, $/Mg (ton)	$39.15 ($35.50)	$39.15 ($35.50)	$59-$70 ($54-$64)	$62-$70 ($57-$64)	$62-$78 ($57-$71)
	Average sales price (natural source), f.o.b. mine or plant $/Mg (ton)	$24.56 ($22.27)	$27.97 ($25.36)	$37.35 ($33.87)	$46.54 ($42.20)	$55.37 ($50.20)
Producer stocks at yearend, natural		83 (92)	95 (105)	71 (79)	165 (182)	72 (80)
Employment:	Mine and plant	1,070	1,330	2,651	2,765	2,905

Source: Commodity Data Summaries Annual, 1977, U.S. Bureau of Mines.

Salient statistics for the U.S. sodium sulfate industry are presented in the following table.

Table 8.14 U.S. SODIUM SULFATE INDUSTRY (in thousand Mg and thousand short tons in parentheses)

	1972	1973	1974	1975	1976
Production: Natural	635 (701)	609 (672)	620 (684)	604 (667)	594 (656)
By-product	567 (626)	694 (766)	602 (664)	507 (560)	548 (605)
Imports for consumption	271 (299)	290 (320)	340 (375)	258 (285)	314 (347)
Exports	26 (29)	40 (45)	46 (51)	69 (77)	44 (49)
Apparent consumption (natural and by-product)	1,449 (1,598)	1,553 (1,713)	1,516 (1,672)	1,301 (1,435)	1,414 (1,559)
Price: Quoted (salt cake - 100 % Na_2SO_4, in carlots bulk at works, \$/Mg (per ton)	\$30 (\$28)	\$30 (\$28)	\$34 (\$31)	\$66 (\$60)	\$71 (\$65)
Average sales price (natural source), f.o.b. mine or plant, \$/Mg (per ton)	\$17.93 (\$16.26)	\$19.03 (\$17.26)	\$26.46 (\$23.99)	\$45.75 (\$41.48)	(\$54.85 (\$49.73)
Producer stocks at year-end, natural	80 (89)	80 (89)	29 (32)	30 (34)	34 (38)
Employment: Wells & Plant	105	132	126	130	135

Source: Commodity Data Summaries Annual, 1977, U.S. Bureau of Mines.

The manufacture of glass absorbs from 39 to 49 percent of the soda ash production and about 7 percent of the sodium sulfate output. The pulp and paper industry consumes about 70 percent of the sodium sulfate output and about 9 percent of the soda ash supply. The production of detergents also requires both compounds: about 20 percent of the sodium sulfate supply and 4 to 6 percent of the soda ash production. In addition, 23 to 25 percent of the soda ash supply is used in producing other chemicals, and about 3 percent is used in water treatment. Miscellaneous uses absorb the remaining soda ash output and 3 percent of the sodium sulfate production.

Reserves of natural sodium sulfate in the United States are limited, and present requirements are met by imported material. If there is no interruption in flow of sodium sulfate from Canada, however, there is little likelihood of a real shortage of salt cake.

8.1.3 NON-METALLIC MINERALS FOR CERAMIC, REFRACTORY AND MISCELLANEOUS INDUSTRIES

8.1.3.1 Clays

8.1.3.1.1. General

Clays are a group of important fine-grained non-metallic minerals which are mostly hydrous aluminum silicates containing various amounts of organic and inorganic impurities.

8.1.3.1.2 U.S. Plants/Companies

Most clays are mined by open pit methods, but in a few instances underground methods are used. About 2 percent of the U.S. total clay output is from underground mines.

Kaolin has many industrial applications, and many grades are specifically designed for use in paper, paints, rubber, plastics and ceramics.

Most of the large kaolin producers have principal operations in Georgia. In 1975 three large diversified firms accounted for about 36% of the total domestic output, and four refractories manufacturers mined 10 percent of the U.S. total for their own use. A total of 35 smaller companies accounted for the balance. Altogether 52 firms operated 120 mines in 14 States.

Ball clay is used primarily in production of whiteware because of its extremely refractory nature. The ball clay industry is small, with 11 producers operating 52 mines in 8 States in 1975. Two of these were large diversified firms with widespread foreign and domestic mineral interests.

Fire clay producers were mostly refractories manufacturers that used the clays in firebrick and other refractories. A large part of the fire clay was mined and used by producers of structural clay products.

In 1975 there were 7 firms producing bentonite from 498 mines in 13 States. Four were large diversified firms with international mineral operations; two of the firms had interests in other types of clay in the United States.

Seven of the 17 fuller's earth producers and 11 of the mines were located in the attapulgite fuller's earth areas of Florida and Georgia. Production, mostly small scale, was reported from seven other States in 1975. Most producers were small independent firms, but four were large diversified corporations with international mineral interests.

Firms producing miscellaneous clay in 1975 were manufacturers of structural clay products, clay pipe, lightweight aggregates, and cement. Essentially all were integrated to the extent of owning and operating the deposits of clay used in making their products. A few of the miscellaneous clay producers were diversified firms having interest in metals and other non-clay products. Some of the miscellaneous clay producers had numerous plants. This is necessary if they are to be major firms, because the economic shipping radius for the individual plants is usually about 200 miles.

Most clay industry plants produce 3-136 Mg (4-150 tons) per hour of product.

Employment in the clay industries totaled 16,000 in 1975. Approximately one-fourth of the workers were involved in mining and exploration, and the balance were engaged in processing the clays for various end uses. Although employment was widespread, certain areas had disproportionately large percentages of the clay workers. An estimated 80 percent of the kaolin employment was in Georgia, and over 90 percent of the fuller's earth workers were in Florida and Georgia. Ohio, Missouri, and Pennsylvania accounted for over 50 percent of the fire clay employment.

8.1.3.1.3 U.S. Production, Consumption, and Price

Salient statistics for the U.S. clay industry are presented in the following table. (Data in 1000 Mg; 1,000 short tons in parentheses.)

Table 8.15 U.S. CLAY INDUSTRY (in thousand Mg and thousand short tons in parentheses)

	1972	1973	1974	1975	1976
Mine production:					
Kaolin	4,823 (5,318)	5,435 (5,933)	5,798 (6,393)	4,837 (5,334)	5,188 (5,720)
Ball clay	612 (675)	695 (767)	741 (817)	640 (706)	782 (863)
Fire clay 1/	3,247 (3,581)	3,689 4,068)	3,755 (4,141)	2,959 (3,263)	3,111 (3,431)
Bentonite	2,509 (2,767)	2,787 (3,073)	3,002 (3,310)	2,928 3,229)	3,417 (3,768)
Fuller's earth	896 (988)	1,032 (1,138)	1,111 (1,225)	1,078 (1,189)	1,161 (1,303)
Common clay	41,837 (46,127)	44,725 (49,312)	40,733 (44,910)	32,040 (35,326)	34,401 (37,929)
Total	53,926 (59,456)	58,366 (64,351)	55,141 (60,796)	44,485 (49,047)	48,083 (53,014)
Imports for consumption	60 (67)	48 (53)	39 (43)	34 (38)	36 (40)
Exports	1,675 (1,847)	1,901 (2,097)	2,223 (2,451)	2,099 (2,315)	2,240 (2,470)
Apparent consumption	52,312 (57,676)	56,512 (62,307)	52,957 (58,388)	42,420 (46,770)	43,879 (50,584)
Price:	$1.10 to $221/Mg ($1.00 to $200 per short ton), depending on type and quality.				
Stocks, yearend	Not Available				
Employment: Mine e/	4,000	4,000	3,800	3,500	3,300
Mill e/	14,000	14,000	13,500	13,000	12,500

Source: Commodity Data Summaries Annual, 1977, U.S. Bureau of Mines.

Production of miscellaneous clays is tied primarily to the construction industry, while output of the higher quality clays is not dependent on demand by a single major industry segment. Miscellaneous clay production is widespread, with all States contributing to the national total in most years. Fire clay output is also widespread, with over half of the States reporting production. About half the fire clay output is used for construction products. Output of the other clays is more restricted geographically because of the lack of resources in many States.

The major world uses for clays are in manufacture of heavy clay construction products, cement, and lightweight aggregates. The more advanced industrial areas, particularly the United States, Western Europe, Canada, and Japan, require substantial quantities of the higher quality clays for use in such products as paper, high-grade ceramics, iron ore pellets, absorbents, and drilling fluids.

Although there are other materials such as talc, silica, and calcium carbonate that can be substituted for high-quality clays in many end uses, the comparatively low cost of clays usually gives them a decided competitive advantage. Alternative materials, therefore, pose no great threats to the specialty clay industries; on the contrary, the competition is more likely to result in increased clay use at the expense of the alternate materials.

For common, or miscellaneous clay, many alternate construction products and raw materials compete very effectively with brick, tile, and lightweight aggregates. A few of the major ones are wall panels made of concrete, stone, glass, metals, and plastics; lightweight aggregates made of pumice, expanded vermiculite, and sintered fly ash; floor and wall tile made of plastics, vinyl asbestos, cork, and concrete; and sewer pipe made of concrete, asbestos, and plastics.

8.1.3.2 Feldspar

8.1.3.2.1 General

Feldspar, usually of the potash or soda type or in mixtures of the two, finds its principal end uses in the manufacture of glass and ceramics; in both of which applications it acts as a flux. In glassmaking, feldspar also provides a source of alumina, the presence of which enhances the workability of the product, inhibits any tendency toward its devitrification, and increases its chemical stability.

8.1.3.2.2 U.S. Companies/Plants

Crude feldspar is produced in the United States as a primary product by large diversified firms, by major firms that are primarily feldspar producers, and by a large number of individuals or groups that mine small quantities for sale to firms that operate feldspar-grinding plants.

Most of the feldspar used in glass making is ground no finer than 20 mesh while that used in ceramics and filler applications is usually pulverized to at least minus 200 mesh.

Nine domestic companies, operating fifteen plants in nine States, ground feldspar for market in 1974. Listed in descending order of output tonnages, North Carolina had six grinding mills, while Connecticut, Georgia, and South Carolina had one each.

8.1.3.2.3 U.S. Production, Consumption and Prices

Salient statistics for the U.S. feldspar industry are presented in the following table.

Table 8.16 U.S. FELDSPAR INDUSTRY (in thousand Mg and thousand short tons in parentheses)

	1972	1973	1974	1975	1976
Production	676 (746)	718 (792)	692 (763)	607 (670)	637 (725)
Imports for consumption	1	--	--	--	--
Exports	4 (5)	9 (10)	16 (18)	9 (10)	6 (7)
Apparent consumption	617 (681)	697 (769)	696 (768)	598 (660)	634 (700)
Price, average, Mg (per ton)	\$15.61 (\$14.16)	\$17.86 (\$16.20)	\$16.47 (\$14.94)	\$19.30 (\$17.50)	\$19.85 (\$18.00)
Stocks, producer, yearend	225 (249)	237 (262)	216 (239)	216 (239)	233 (257)
Employment: Mine and preparation plant	450	450	450	450	450

Source: Commodity Data Summaries Annual, 1977, U.S. Bureau of Mines.

Feldspar is a relatively unimportant item in U.S. foreign trade, although in some areas, particularly in the northeastern States, a significant proportion of the feldspathic-materials demand is satisfied by an alternative mineral product, nepheline syenite, imported from Canada.

Feldspar is a relatively low-priced, bulk commodity that usually can be produced from some source near the consumer more advantageously than it can be shipped from a distance.

8.1.3.3 Kyanite

8.1.3.3.1 General

Kyanite, andalusite, and sillimanite are a closely related trio of aluminum silicate minerals that break down upon heating to form a mixture of mullite, $3Al_2O_3.2SiO_2$, and vitreous silica, SiO_2. The properties of mullite serve to advantage as a component in refractory shapes and furnace linings for a wide range of industrial applications.

8.1.3.3.2 U.S. Companies/Plants

All but a small part of the domestic kyanite output in recent years has consisted of the contributions of only two firms. Kyanite Mining Corp. operates two mines in Virginia, the Willis Mountain mine at Dillwyn in Buckingham County and the Baker Mountain mine in adjacent Prince Edward County. Commercialores, Inc., a subsidiary of Combustion Engineering, Inc., worked the Henry Knob mine in York County, South Carolina, from 1948 through 1969, and C-E Minerals, Inc., another division of Combustion Engineering, Inc., has operated the Graves Mountain mine in Lincoln County, Georgia, since 1963.

8.1.3.3.3 U.S. Production, Consumption, and Prices

Salient statistics for the U.S. kyanite industry are presented in the following table.

Table 8.17 U.S. KYANITE INDUSTRY (in thousand Mg and thousand short tons in parentheses)

	1972	1973	1974	1975	1976
Production: Mine	Company confidential data				
Synthetic mullite	42.1 (46.4)	52.8 (58.2)	37.6 (41.5)	21.9 (24.1)	27.2 (30.0)
Imports for consumption	0.1	0.2	0.2	0.1	0.1
Exports e/	27.2 (30.0)	40.1 (45.0)	40.1 (45.0)	40.1 (45.0)	40.1 (45.0)
Apparent consumption	Not Available				
Price: Domestic concentrate, 35- to 325- mesh, in bags, f.o.b. Georgia $69-$130/Mg ($63 to $118 per short ton); imported kyanite, no current quotation; synthetic mullite, $177-$496/Mg ($160 to $450 per short ton), depending upon type and grade.					
Stocks (producer)	Not Available				
Employment: Kyanite mine and plant	165	175	175	175	175

Source: Commodity Data Summaries Annual, 1977, U.S. Bureau of Mines.

In accordance with the policy of the firms involved, no statistics on U.S. production of kyanite have been released since 1948-49 when the then-current figure was in the neighborhood of 12,244 Mg (13,500 tons) per year. Published estimates from various sources since then have placed the U.S. output at about 40,814 Mg (45,000 tons) in 1963 and 85,258 Mg (94,000 tons) in 1973. Both figures, although useful as indicators of magnitudes, are believed to be moderately in error on the conservative side.

Statistical consumption data is not available. Refractory uses have been dominant since the early 1920's. Many non-refractory uses for the kyanite-group minerals and synthesized aluminum silicates have been developed, and other possible uses appear to have potential for future large-scale applications.

In the iron and steel industries, mullite has found important use in critical areas of blast furnace stoves and stacks, reheat furnaces, steel degassing chambers and soaking pits, and many types of auxillary pouring and handling equipment.

8.1.3.4 Talc

8.1.3.4.1 General

The mineral talc is a soft, hydrous magnesium silicate. Commercial talcs range from something approaching pure mineral composition to mineral products that have properties in common with pure talc but which may contain very little of the actual minerals.

8.1.3.4.2 Company/Plant Statistics

Talc or soapstone was produced domestically in 1974 from 46 mines in Alabama, Arkansas, California, Georgia, Maryland, Montana, Nevada, New York, North Carolina, Oregon, Texas, Vermont, Virginia, and Washington.

Pyrophyllite was produced from five mines in North Carolina and one mine in Pennsylvania.

There were 30 producers of talc minerals in the U.S. in 1974. The plant size range is from 5-18 mg (6 to 20 tons) per hour.

The largest producers of talc minerals in the United States (all either exclusively engaged in that enterprise or else horizontally integrated subsidiaries of diversified organizations) jointly provided 75 percent of the total 1974 domestic output, and the remainder consisted of the combined contributions of about 25 smaller firms.

The principal domestic producers of crude talc, soapstone, and pyrophyllite approached vertical integration to some degree in that they operated grinding mills, processing their output either in plants adjacent to the mines or in separate installations more conveniently located with respect to major markets. Part of the mineral from California and Montana was milled in Oregon, and a substantial quantity of Montana talc was processed in Belgium.

Employment in talc, soapstone, and pyrophyllite mines and preparation plants in 1974 was estimated to be equivalent to the services of about 950 full-time workers.

8.1.3.4.3 U.S. Production, Consumption, and Prices

Salient statistics for the U.S. talc industry are presented in Table 8-18.

The largest use of talc-group minerals is for the manufacture of ceramics. In this application, addition of talc or pyrophyllite to the usual clay-silica-feldspar body mixtures facilitates the firing of the ware and improves the quality. Second in rank for end use is paint production. Third in order

Table 8.18 U.S. TALC INDUSTRY (in thousand Mg and thousand short tons in parentheses)

	1972	1973	1974	1975	1976
Production: Mine	1,004 (1,107)	1,131 (1,247)	1,150 (1,268)	875 (965)	1,028 (1,134)
Sold by producers	983 (1,084)	1,073 (1,184)	965 (1,064)	844 (931)	907 (1,000)
Imports for consumption	26 (29)	20 (23)	27 (30)	20 (23)	20 (23)
Exports	155 (171)	163 (180)	165 (183)	143 (158)	175 (194)
Apparent consumption 1/	854 (942)	931 (1,027)	826 (911)	721 (796)	751 (829)
Price: $5.50-$276.00/Mg ($5 to $250 per ton) (crude or ground) depending upon grade and preparation					
Stocks, producer, yearend	151 (167)	142 (157)	188 (208)	231 (255)	208 (230)
Employment: Mine and mill	950	950	950	950	950

Source: Commodity Data Summaries Annual, 1977, U.S. Bureau of Mines.

among outlets for domestic talc minerals is use for coating and/or loading of high-quality papers. In this application, high-purity talc helps in obtaining a product with the desired weight and opacity, good ink retention, and superior surface texture.

Specific end-use percentages of total consumption are: Ceramics - 17%, paint - 12%, toilet/cosmetic - 3%, insecticides - 4%, paper - 7%, refractories - 3% roofing - 4% rubber - 2%, and all other minor uses - 46%.

The bulk of the talc, soapstone, and pyrophyllite of commerce is made up of relatively low-unit-value material unable to bear the charges of long-distance transportation, but exceptional grades such as high-purity talc of pharmaceutical, cosmetic, or even papermaking quality are significant items of international trade. The quantities of talc, soapstone, and pyrophyllite imported and exported by the United States, however, are relatively too small to exert a decisive influence on the overall pattern of the industry, even though the total values involved are substantial.

8.1.4 Bibliography

The industry structure presented here has been compiled from information obtained from the United States Bureau of Mines in Washington, D.C. The Bureau of Mines is considered to be the definitive source for U.S. mineral industry data. The text is comprised of quoted, paraphrased and edited material from preprints of the 1975 edition of Mineral Facts and Problems. Individual physical scientists in the Division of Non-Metallic Minerals at the Bureau whose reports make up the lion's share of this document are:

1. Sand and gravel: Walter Pajalich, mining engineer, Division of Non-Metallic Minerals (DNM)
2. Gypsum: Avery H. Reed, Supervisory Physical Scientist, DNM
3. Pumice, Perlite, Arthur C. Meisinger, Industry Economist, DNM
4. Vermiculite: Richard H. Singleton, Physical Scientist, DNM
5. Mica: Stanley K. Haines, Physical Scientist, DNM
6. Barite: Frank B. Fulkerson, Industry Economist, DNM
7. Fluorspar: Hiram B. Wood, Ecologist, DNM
8. Salt: Charles L. Klingman, Physical Scientist, DNM
9. Boron: K.P. Wang, Supervisory Physical Scientist, DNM
10. Clays: Sarkis G. Ampian, Physical Scientist, DNM
11. Talc, Feldspar: J. Robert Wells, Physical Scientist, DNM
12. Kyanite: Michael J. Potter, Physical Scientist, DNM

Space limitations do not permit listing individual authors' bibliographies here. The 1975 Mineral Facts and Problems preprints contain these listings and are available from the Bureau of Mines.

Data presented from these reports have been supplemented with the 1955, 1960, 1965, 1970, 1971, 1972, and 1973 Minerals Yearbooks (Vol. I): 1974 & 1975 Minerals Yearbook Preprints; 1976 and 1977 Commodity Data Summaries; 1970 edition of Mineral Facts and Problems; 1975 Mineral Facts and Problems Preprints; Mineral Industry Annual Advance Summaries; and personal communications with most of the individual authors as well as data clerks and statisticians at the Bureau of Mines. Certain statistical items are quoted from "Engineering/Mining Journal", "Pit and Quarry", "Rock Products", "Chemical Market Reporter" and are referenced in the text. It is neither the intent nor desire of the editor of this document to claim authorship for all or any part of the text of the individual industry structures included herein.

8.2 COST ANALYSIS OF ALTERNATIVE EMISSION CONTROL SYSTEMS

8.2.1 Introduction

For costing purposes, two model non-metallic plants have been developed, representative of typical new stationary plants in each of the 18 industries studied in this document. In addition, costs have been developed for a model portable plant, typifying a crushed stone or sand and gravel installation. These costs are found in Supplement A.

The first model plant consists of crushing operations only, and includes: primary and secondary crushers, screens (3), transfer points (4) and the loading operation. The second model plant includes both a crushing operation and a grinding operation, the latter consisting of a grinder, another screen, two additional transfer points, and a bagging machine.

Costs are presented in this section for controlling particulate emissions from these model new plants to achieve the alternative emission level considered in this document.

Particulate control costs have also been developed for expansions at existing non-metallic minerals plants. The model plant selected here consists only of a grinding operation, since crushing operations are usually built with excess capacity, thus obviating the need for additional equipment. (Refer to Section 8.2.3 for more detailed information.)

(Costs have also been developed for monitoring particulate emissions at the model plants. However, since the anticipated new source performance standard (NSPS) is not expected to require such monitoring, these costs are treated separately in Section 8.3.)

All control costs have been based on technical parameters associated with the control system used, such as the plant capacity. These parameters are listed in Table 8.19.

These model plant costs cannot be assumed to reflect costs of any given installation. Estimating control costs for an actual installation requires performing detailed engineering studies. Nonetheless, for purposes of this analysis, model plant costs are considered to be sufficiently accurate.

The model plant costs have been based primarily on data available from an EPA contractor (Industrial Gas Cleaning Institute), who had in turn obtained control system costs from vendors of air pollution control equipment.[2] These costs have been supplemented by a compendium of costs for selected air pollution control systems.[3] The monitoring costs have been obtained from an equipment vendor.[8]

Two cost parameters have been developed: installed capital and total annualized. The installed capital costs for each emission control system include the purchased costs of the major and auxiliary equipment, costs for site preparation and equipment installation, and design engineering costs. No attempt has been made to include costs for research and development, possible lost production during equipment installation, or losses during startup. All capital costs in this section reflect fourth quarter 1976 prices for equipment, installation materials, and installation labor.

Table 8.19 TECHNICAL PARAMETERS USED IN DEVELOPING CONTROL SYSTEM COSTS[a]

Parameter	Value
1. Temperature	21°C (70°F)
2. Volumetric flowrate	(See Tables 8.22 to 8.33, 8.38, & 8.39)
3. Moisture content	2 percent (by volume)
3. Particulate loadings:	
Inlet	12.8 g/Nm^3 (5.6 grains/scf)
Outlet	0.050 g/Nm^3 (0.02 grains/scf)
4. Plant capacities[b]	9.1, 23, 68, 135, 180, 270, and 540 Mg/hr (10, 25, 75, 150, 200, 300, and 600 tons/hr)
5. Operating factors:	
Crushing operations	2,000 hours/year
Grinding operations	8,400 hours/year

---

[a] Reference 1.

[b] These capacities represent the sizes typical of generalized model plants. However, for a particular industry, only some of these sizes are applicable.

The total annualized costs consist of direct operating costs and annualized capital charges. Direct operating costs include fixed and variable annual costs, such as:

- Labor and materials needed to operate control equipment;
- Maintenance labor and materials;
- Utilities, such as electric power;
- Replacement parts;
- Dust disposal (where applicable).

The dust disposal costs apply only to dry collection systems (i.e., fabric filters) used to control crushing operations when no grinding operations are employed. A unit cost of \$4.40/Mg (\$4/ton) is used to cover the costs of trucking the collected particulate to a disposal point on-site (e.g., the mine).[4]

In those plants that have both crushing and grinding operations, the dust collected by the crusher baghouses is conveyed to the grinder, while the particulate captured by the grinder fabric filter is recycled as finished product. In this case, it has been assumed that the dust recovery credit offsets the cost of recycling. That is, neither a dust credit nor a cost is included in the direct operating cost.

The annualized capital charges account for depreciation, interest, administrative overhead, property taxes, and insurance. The depreciation and interest have been computed by use of a capital recovery factor, the value of which depends on the depreciable life of the control system and the interest rate. (An annual interest rate of 10 percent and a 20 year depreciable life have been assumed herein.) Administrative overhead, taxes, and insurance have been fixed at an additional 4 percent of the installed capital cost per year. The annual cost factors in this section are listed in Table 8.20.

Finally, the total annualized cost is obtained simply by adding the direct operating cost to the annualized capital charges.

8.2.2 New Facilities

As discussed in section 8.2.1, two new model plants have been developed for costing purposes: a stationary installation with crushing operations only (Model Plant 1) and another stationary with both crushing and grinding operations (Model Plant 2). The model plant developed for costing the portable plant segments of the crushed stone, and sand and gravel industries is discussed in Supplement A. For both models, the alternative emission level to be achieved is 0.050 g/dscm (0.02 grains/dscf). The control option to be used to achieve this emission level is fabric filtration. At an uncontrolled emission rate of 12.8 g/dscm (5.6 grains/dscf) (see Table 8.19), this control option is 99.6 percent efficient in removing particulate at the model plants.

The size and number of fabric filter systems required to achieve the emission limit vary according to the mineral plant capacity. For example, only two moderately-sized baghouses are required to control the crushing and grinding operations at the 9.1 Mg/hour (10 tons/hour) model plant, while four much larger fabric filters are needed at the 540 Mg/hour (600 tons/hour) model.

Each of these fabric filter systems consists of a pulse-jet baghouse with polypropylene bags, fan and fan motor, dust hopper, screw conveyor, ductwork, and stack.

Table 8-20. ANNUALIZED COST PARAMETERS[a]

Parameter	Value
1. Operating Labor	\$10/man-hour
2. Maintenance Labor	50 percent of operating labor (fabric filters) 40 man-hours/year (opacity monitors)
3. Maintenance Materials	2 percent of maintenance labor (fabric filters) 1 percent of total installed cost (opacity monitors)
4. Utilities:	
Electric Power	\$0.03/kw-hr
5. Replacement Parts:	
Polypropylene Bags	\$7.00/m^2 (\$0.65/ft^2)
6. Dust disposal	\$4.40/Mg (\$4.00/ton)
7. Depreciation and Interest	11.75 percent of total installed cost (fabric filters) 16.28 percent of total installed cost (opacity monitors)
8. Taxes, Insurance, and Administrative Charges	4.0 percent of total installed cost

[a] References 2, 3, 4, and EPA estimates.

Tables 8-21 through 8-26 list installed capital, direct operating, annualized capital, and total annualized costs for each of the fabric filter systems installed in the new Model Plants 1. The six plant sizes for which costs have been developed cover the range in capacities applicable to the various mineral industries.

In Tables 8-21 through 8-24, the first column lists the technical or cost parameter in question. The data pertaining to the fabric filter are listed in the second column. However, in each of Tables 8-25 and 8-26, more than one fabric filter are needed to control the crushing operation. The data for these fabric filters appear in columns 2, 3, etc., while the right-hand column lists the totals for the model plant.

Similarly, Tables 8-27 through 8-32 contain cost data for Model Plant 2. The costs are itemized according to the fabric filters controlling the crusher and grinder operations, respectively. Again, the right-hand column lists data for the total model plant. Note that the installed capital costs and annualized capital charges for the crusher baghouse(s) are the same as in the corresponding tables for Model Plant 1. However, because no dust disposal costs are included with Model Plant 2, the direct operating costs--and the total annualized costs--are lower.

In these tables, the total annualized cost has been expressed in two ways: thousand dollars/year and dollars/megagram of product. The latter expression is the quotient of the total annualized cost and the annual production rate, based, in turn, on the operating factor. As Table 8-19 indicates, crushing operations (i.e., Model Plant 1) are assigned an operating factor of 2,000 hours/year, while with grinding operations,

Table 8-21 FABRIC FILTER COSTS FOR NEW MODEL PLANT 1: 9.1 Mg/Hour (10 tons/hour) Capacity[a]

Parameter	Value
Gas flowrate, m^3/min. (ACFM)	289 (10,200)
Installed capital cost, M$[b]	60
Direct operating cost, M$/yr	4.7
Annualized capital charges, M$/yr	9.5
Total annualized cost, M$/yr	14.2
$/Mg product[c]	0.78
Cost-effectiveness, $/Mg particulate removed[c]	32.1

[a] References 1 to 4.

[b] The letter "M" denotes thousands; "MM" denotes millions, etc.

[c] Quotients are based on 2,000 hours/year operating factor.

Table 8-22 FABRIC FILTER COSTS FOR NEW MODEL PLANT 1: 23 Mg/Hour (25 tons/hour) Capacity[a]

Parameter	Value
Gas flowrate, m^3/min (ACFM)	325 (11,500)
Installed capital cost, M$[b]	67
Direct operating cost, M$/yr	5.3
Annualized capital charges, M$/yr	10.5
Total annualized cost, $/yr	15.8
$/Mg product[c]	0.34
Cost-effectiveness, $/Mg particulate removed[c]	31.7

[a] References 1 to 4.

[b] The letter "M" denotes thousands; "MM" denotes millions, etc.

[c] Quotients based on 2,000 hours/year operating factor.

Table 8-23 FABRIC FILTER COSTS FOR NEW MODEL PLANT 1: 68 Mg/Hour (75 tons/hour) Capacity[a]

Parameter	Value
Gas flowrate, m^3/min (ACFM)	504 (17,800)
Installed capital cost, M$[b]	95
Direct operating cost, M$/yr	8.4
Annualized capital charges, M$/yr	15.0
Total annualized cost, M$/yr	23.4
$/Mg product[c]	0.17
Cost-effectiveness, $/Mg particulate removed[c]	30.3

[a] References 1 to 4.

[b] The letter "M" denotes thousands; "MM" denotes millions, etc.

[c] Quotients are based on 2,000 hours/year operating factor.

Table 8-24. FABRIC FILTER COSTS FOR NEW MODEL PLANT 1: 135 Mg/Hour (150 tons/hour) Capacity[a]

Parameter	Value
Gas flowrate, m^3/min (ACFM)	708 (25,000)
Installed capital cost, M$[b]	122
Direct operating cost, M$/yr	11.9
Annualized capital charges, M$/yr	19.2
Total annualized cost, M$/yr $/Mg product[c]	31.1 0.12
Cost-effectiveness, $/Mg particulate removed[c]	28.7

[a] References 1 to 4.

[b] The letter "M" denotes thousands; "MM" denotes millions, etc.

[c] Quotients are based on 2,000 hours/year operating factor.

Table 8-25. FABRIC FILTER COSTS FOR NEW MODEL PLANT 1: 270 Mg/Hour (300 tons/hour) Capacity[a]

Parameter	Value		
	Fabric Filter 1	Fabric Filter 2	Total
Gas flowrate, m^3/min (ACFM)	1,130 (40,000)	226 (8,000)	1,360 (48,000)
Installed capital cost, M$[b]	161	50	211
Direct operating cost, M$/yr	18.6	3.7	22.3
Annualized capital charges, M$/yr	25.3	7.9	33.2
Total annualized cost, M$/yr	43.9	11.6	55.5
$/Mg product[c]	0.081	0.021	0.10
Cost-effectiveness, $/Mg particulate removed[c]	25.3	33.5	26.7

[a] References 1 to 4.

[b] The letter "M" denotes thousands; "MM" denotes millions, etc.

[c] Quotients are based on 2,000 hours/year operating factor.

Table 8-26. FABRIC FILTER COSTS FOR NEW MODEL PLANT 1: 540 Mg/Hour (600 tons/hour) Capacity[a]

Parameter	Value			
	Fabric Filter 1	Fabric Filter 2	Fabric Filter 3	Total
Gas flowrate, m^3/min (ACFM)	225 (9,000)	906 (32,000)	877 (31,000)	2,040 (72,000)
Installed capital cost, M$[b]	54	142	140	336
Direct operating cost, M$/yr	4.1	15.1	14.6	33.9
Annualized capital charges, M$/yr	8.5	22.4	22.1	53.0
Total annualized cost, M$/yr	12.6	37.5	36.7	86.9
$/Mg product[c]	0.012	0.035	0.034	0.080
Cost-effectiveness, $/Mg particulate removed[c]	32.3	27.0	27.3	27.8

[a] References 1 to 4.

[b] The letter "M" denotes thousands; "MM" denotes millions, etc.

[c] Quotients are based on 2,000 hours/year operating factor.

Table 8-27. FABRIC FILTER COSTS FOR NEW MODEL PLANT 2: 9.1 Mg/Hour (10 tons/hour) Capacity[a]

	Value		
Parameter	Fabric Filter 1	Fabric Filter 2	Total[b]
Operation controlled	Crushing	Grinding	--
Gas flowrate, m^3/min. ACFM	289	113	--
	(10,200)	(4,000)	--
Installed capital cost, M$[c]	60	33	93
Direct operating cost, M$/yr	2.7	3.8	6.5
Annualized capital charges, M$/yr	9.5	5.2	14.7
Total annualized cost, M$/yr	12.2	9.0	21.2
$/Mg Product[d]	0.67	0.12	0.28
Cost-effectiveness, $/Mg particulate removed[d]	27.6	12.4	18.2

[a] References 1 to 3.

[b] Numbers in the right-hand column pertain to combined crushing and grinding operations.

[c] The letter "M" denotes thousands; "MM" denotes millions, etc.

[d] Quotients for crushing are based on 2,000 hours/year operating factor; grinding quotients based on 8,400 hours/year.

Table 8-28. FABRIC FILTER COSTS FOR NEW MODEL PLANT 2: 23 Mg/Hour (25 tons/hour) Capacity[a]

Parameter	Value		
	Fabric Filter 1	Fabric Filter 2	Total[b]
Operation controlled	Crushing	Grinding	--
Gas flowrate, m^3/min (ACFM)	325 (11,500)	133 (4,700)	-- --
Installed capital cost, M$[c]	67	36	103
Direct operating cost, M$/yr	3.1	4.1	7.2
Annualized capital charges, M$/yr	10.5	5.7	16.2
Total annualized cost, $/yr	13.6	9.8	23.4
$/Mg product[d]	0.30	0.05	0.12
Cost-effectiveness, $/Mg particulate removed[d]	27.4	11.5	17.3

[a] References 1 to 3.

[b] Numbers in the right-hand column pertain to combined crushing and grinding operations.

[c] The letter "M" denotes thousands; "MM" denotes millions, etc.

[d] Quotients for crushing based on 2,000 hours/year operating factor; grinding quotients based on 8,400 hours/year.

Table 8-29. FABRIC FILTER COSTS FOR NEW MODEL PLANT 2: 68 Mg/Hour (75 tons/hour) Capacity[a]

Parameter	Value		
	Fabric Filter 1	Fabric Filter 2	Total[b]
Operation controlled	Crushing	Grinding	--
Gas flowrate, m^3/min (ACFM)	504 (17,800)	190 (6,700)	--
Installed capital cost, M$[c]	95	44	139
Direct operating cost, M$/yr	5.0	5.1	10.1
Annualized capital charges, M$/yr	15.0	6.9	21.9
Total annualized cost, M$/yr	20.0	12.0	32.0
$/Mg product[d]	0.15	0.021	0.056
Cost-effectiveness, $/Mg particulate removed[d]	25.9	9.83	16.1

[a] References 1 to 3.

[b] Numbers in the right-hand column pertain to combined crushing and grinding operations.

[c] The letter "M" denotes thousands; "MM" denotes millions, etc.

[d] Quotients for crushing are based on 2,000 hours/year operating factor; grinding quotients based on 8,400 hours/year.

Table 8-30. FABRIC FILTER COSTS FOR NEW MODEL PLANT 2: 135 Mg/hour (150 tons/hour) Capacity[a]

Parameter	Value		
	Fabric Filter 1	Fabric Filter 2	Total[b]
Operation controlled	Crushing	Grinding	--
Gas flowrate, m^3/min (ACFM)	708 (25,000)	320 (11,300)	-- --
Installed capital cost, M$[c]	122	65	187
Direct operating cost, M$/yr	7.1	7.8	14.9
Annualized capital charges, M$/yr	19.2	10.3	29.5
Total annualized cost, M$/yr $/Mg product[d]	26.3 0.097	18.1 0.016	44.4 0.039
Cost-effectiveness, $/Mg particulate removed[d]	24.3	8.80	14.1

[a] References 1 to 3.

[b] Numbers in the right-hand column pertain to combined crushing and grinding operations.

[c] The letter "M" denotes thousands; "MM" denotes millions, etc.

[d] Quotients for crushing are based on 2,000 hours/year operating factor; grinding quotients based on 8,400 hours/year.

Table 8-31. FABRIC FILTER COSTS FOR NEW MODEL PLANT 2: 270 Mg/Hour (300 tons/hour) Capacity[a]

Parameter	Value			
	Fabric Filter 1	Fabric Filter 2	Fabric Filter 3	Total[b]
Operation controlled	Crushing	Crushing	Grinding	--
Gas flowrate, m^3/min (ACFM)	1,130 (40,000)	226 (8,000)	640 (22,600)	-- --
Installed capital cost, M$[c]	161	50	113	324
Direct operating cost, M$/yr	10.9	2.2	17.4	30.5
Annualized capital charges, M$/yr	25.3	7.9	17.8	51.0
Total annualized cost, M$/yr	36.2	10.1	35.2	81.5
$/Mg product[d]	0.067	0.019	0.016	0.036
Cost-effectiveness, $/Mg particulate removed[d]	20.9	29.2	8.56	13.2

[a] References 1 to 3.

[b] Numbers in the right-hand column pertain to combined crushing and grinding operations.

[c] The letter "M" denotes thousands; "MM" denotes millions, etc.

[d] Quotients for crushing are based on 2,000 hours/year operating factor; grinding quotients based on 8,400 hours/year.

Table 8-32. FABRIC FILTER COSTS FOR NEW MODEL PLANT 2: 540 Mg/Hour (600 tons/hour) Capacity[a]

Parameter	Value				
	Fabric Filter 1	Fabric Filter 2	Fabric Filter 3	Fabric Filter 4	Total[b]
Operation controlled	Crushing	Crushing	Crushing	Grinding	--
Gas flowrate, m^3/min (ACFM)	255 (9,000)	906 (32,000)	877 (31,000)	1,280 (45,200)	-- --
Installed capital cost, M$[c]	54	142	140	171	507
Direct operating cost, M$/yr	2.4	9.0	8.7	31.1	51.2
Annualized capital charges, M$/yr	8.5	22.4	22.1	26.9	79.9
Total annualized cost, M$/yr	10.9	31.4	30.8	58.0	131.1
$/Mg product[d]	0.010	0.029	0.029	0.013	0.029
Cost-effectiveness, $/Mg particulate removed[d]	27.9	22.7	23.0	7.05	11.6

[a] References 1 to 3.

[b] Numbers in the right-hand column pertain to combined crushing and grinding operations.

[c] The letter "M" denotes thousands; "MM" denotes millions, etc.

[d] Quotients for crushing are based on 2,000 hours/year operating factor; grinding quotients based on 8,400 hours/year.

8,400 hours/year has been used. For Model Plant 2, where both crushing and grinding operations are employed, 8,400 hours/year is used as the operating factor, solely for the purpose of computing the unit annualized costs.

Each cost-effectiveness ratio appearing in the tables is simply the quotient of the total annualized cost and the amount of particulate collected annually by the fabric filter system. To compute the particulate collected, the 2,000 and 8,400 hours/year operating factors are applied, respectively, to the individual crushing and grinding operations. However, for combined crushing and grinding operations, the following expression has been used to calculate cost-effectiveness:

$$\text{Cost-effectiveness} = \frac{TAC_C + TAC_G}{7.65 \times 10^{-7}\,(2000Q_C + 8400Q_G)}$$

($/Mg particulate removed)

Where: TAC_C, TAC_G = total annualized costs for crushing and grinding baghouses, respectively (M$/year)

Q_C, Q_G = total volumetric flowrates for crushing and grinding baghouses, respectively (m^3/min)

The numerator is the sum of the annualized costs for the crushing and grinding operations, while the denominator represents the total amount of particulate removed by the fabric filters controlling these operations. (Cost-effectiveness is further discussed in Section 8.2.4.)

As the tables indicate, the installed costs in the crushing (only) model plant range from $60,000 to $336,000, as the plant capacity goes from 9.1 Mg/hour to 540 Mg/hour. However, given the sixty-fold increase in the plant capacity, the installed costs increase relatively little. This is so because the fabric filter installed costs are a function of the volumetric flowrate, not the plant capacity. Moreover, the volumetric flowrate, while dependent on the capacity, does not increase proportionately with the plant size.

Based on a 2000 hour operating year, the total annualized cost increases from $14,000 to $87,000 per year, corresponding to $0.78 to $0.08/Mg product, as the plant capacity goes from 9.1 to 540 Mg/hour. Ordinarily, one would also expect a more substantial increase in the total annualized cost over such a large range in plant capacities. However, as Tables 8-21 through 8-26 show, the annualized capital charges comprise the bulk of the total annualized costs. And since the annualized capital charges are directly proportional to the installed costs, the total annualized cost very nearly follows the change in the capital cost.

There are several reasons why the direct operating costs are so low. First, because the gas streams controlled are non-corrosive and low-temperature, the fabric filter maintenance is relatively small, amounting to less than one percent of the installed cost annually. Then, because there is a relatively small pressure drop through the baghouse system, the power cost is relatively low. Costs for replacement parts (i.e., bags) are proportional to the gas flowrate, but at the same time amount to a small fraction of the direct operating costs.

A similar pattern appears with the costs for Model Plant 2, which contains both crushing and grinding operations. The costs here are about the same order of magnitude as are those for Model Plant 1. The main difference is the additional baghouse required to control the grinder and its auxiliaries. Here the installed costs range from $93,000 to $507,000, while the annualized costs go from $21,000 to $131,000 per year ($0.28 to $0.03/Mg product, respectively).

The costs described above are for achieving the alternative emission level. It is also necessary to compare these costs to the costs required to meet a typical state emission regulation (SIP) in the model plants. In this analysis, however, it is assumed that the SIP can be met without controls. The SIP or baseline costs are, therefore, zero. Thus, the costs shown in Tables 8-21 to 8-32 are solely attributable to the alternative emission limit.

8.2.3 Modified/Reconstructed Facilities

As Chapter 5 points out, there appears to be no condition which would deem an existing plant modified. Concerning reconstruction, if replacement of components subject to high abrasion and impact, such as crushing and screening surfaces and conveyor belts, are exempted and considered routine for this category of sources, there also appears to be no action which could be construed as reconstruction.

Nonetheless, expansions of existing plants do occur. When they do, only a portion of the plant would be covered under the alternative emission limit. These expansions would more than likely involve the grinding operation, since crushing operations are usually capable of handling increased throughput without additional equipment. However, to expand the plant grinding capacity, a new complete grinding line would be added.

In this document, sizes for three stationary model plants have been developed to cover these expansions: 4.5, 9.1, and 32 Mg/hour (5,10, and 35 tons/hour). The first two sizes apply to all industries employing grinders (i.e., Model Plant 2). The third size applies only to the boron industry.

The option costed for controlling these expanded model plants is fabric filtration. The gas flowrates used in the costing are listed in Tables 8-33 and 8-34. The other technical parameters appear in Table 8-19.

Because these fabric filters would be installed at existing, as opposed to new plants, the installed capital costs are somewhat higher, reflecting the higher installation costs required. The difference between the existing and new plant installation costs, or retrofit penalty, is quite variable, depending on individual plant configuration, on-site utility capacity, and other seemingly random variables. Nonetheless, after polling its members, the Industrial Gas Cleaning Institute has developed an approximate multiplier, or retrofit factor, to be used in estimating the existing plant installation costs.[5] This retrofit factor is 2.0. Using this factor, the control system existing plant installation cost would be twice that of the new plant installation cost.

Table 8-33 lists the costs of fabric filter systems installed in the expanded 4.5 and 9.1 Mg/hour model plants. The 32 Mg/hour capacity model plant costs are listed in Table 8-34.

The installed costs in Table 8-33 are $43,000 and $48,000 for the 4.5 and 9.1 Mg/hour plants, respectively. The installed cost difference is relatively small: 10 percent. However, this is because the gas flowrates upon which the costs are based differ by only 23 percent, even

Table 8-33. FABRIC FILTER COSTS FOR EXPANDED MODEL PLANTS[a,b]

Parameter	Value, by Capacity	
	4.5 Mg/Hour	9.1 Mg/Hour
Gas flowrate, m^3/min (ACFM)	92.0 (3,250)	113 (4,000)
Installed capital cost, M$[c]	43	48
Direct operating cost, M $/yr	3.4	3.8
Annualized capital charges, M$/yr	6.8	7.5
Total annualized cost,[d] M $/yr	10.2	11.3
$/Mg product[e]	0.27	0.15

[a] References 1, 2, 3, and 5.

[b] Expanded plants consist of grinding operations only.

[c] The letter "M" denotes thousands; "MM" denotes millions, etc.

[d] Since SIP control cost is zero, total and incremental annualized costs are equal.

[e] Quotients are based on an 8,400 hours/year operating factor.

Table 8-34. FABRIC FILTER COSTS FOR 32 Mg/Hour EXPANDED MODEL PLANT[a,b]

Parameter	Value
Gas flowrate, m^3/min (ACFM)	184 (6,500)
Installed capital cost, M$[c]	65
Direct operating cost, M$/yr.	5.0
Annualized capital charges, M$/yr.	10.2
Total annualized cost[d]	
M$/year	15.2
$/Mg product[e]	0.057

[a] References 1, 2, 3, and 5.

[b] This capacity applies to the boron industry only

[c] The letter "M" denotes thousands; "MM" denotes millions, etc.

[d] Since SIP control cost is zero, total and incremental annualized costs are equal.

[e] Quotients are based on an 8,400 hours/year operating factor.

though one plant size is twice the other. The total annualized costs differ much less: $10,200/year for the 4.5 Mg/hour size, and $11,300/year for the 9.1 Mg/hour case. (Because these baghouses control grinders, neither of these costs includes a cost for dust disposal.)

Since grinding operations need not be controlled to achieve a state regulation, the SIP costs are zero. The annualized costs shown in Table 8-33 are, therefore, both total and incremental. These incremental costs are $0.27 and $0.15/Mg product, in turn, for the 4.5 and 9.1 Mg/hour capacity plants. Both numbers have been based on an 8400 hours/year operating factor. The 44 percent decrease in cost indicates a positive economy of scale with plant capacity.

Finally, the fabric filter costs for the 32 Mg/hour expanded model plant are listed in Table 8-34. Sized for a gas flow rate of 184 m^3/min, the installed cost is $65,000. The corresponding incremental annualized cost is $15,200 per year, or $0.06/Mg product, based on the same 8400 hours/year operating factor.

8.2.4 Cost-Effectiveness of the Alternative Emission Limit

For each of the control options costed to achieve the alternative emission limit, it is informative to compare the total annualized cost with the amount of particulate removed. A convenient yardstick for expressing this comparison is the cost-effectiveness ratio, which is the quotient of the annualized cost and the quantity of particulate removed annually. Expressed in dollars per megagram of particulate, these ratios appear in Tables 8-21 through 8-32, for the stationary new model plant sizes costed herein. (Because an NSPS impacts most heavily on new, rather than existing plants, the cost-effectiveness analysis will be limited to them.)

It is clear from these tables that the ratios vary according to the plant capacity, design, and the model plant configuration (i.e., Model Plant 1 or 2). For Model Plant 1 (crushing only), the cost-effectiveness ranges from \$32.1 to \$27.8/Mg, as the capacity goes from 9.1 to 540 Mg/hour. The corresponding ratios for Model Plant 2 (crushing and grinding) are \$18.2 and \$11.6/Mg particulate removed.

The ratios are plotted in Figure 8-1 against the model plant capacity. Note, first of all, that with Model Plant 2, the cost-effectiveness decreases from \$18.2 to \$14.1/Mg (23 percent) between the 9.1 and 135 Mg/hour plant capacities. At larger sizes, however, this rate of decrease is much less pronounced. In fact, the cost-effectiveness ratio decreases only 18 percent between 135 and 540 Mg/hour. Nonetheless, the fact that the ratio decreases consistently with plant size indicates that the control costs for Model Plant 2 benefit from a positive economy of scale.

The curve for Model Plant 1 does not exhibit this consistency, however. Note that the cost-effectiveness decreases gradually from a maximum of \$32.1/Mg to a minimum of \$26.5/Mg. This minimum occurs at a plant capacity of about 340 Mg/hour. But for larger plant sizes, the curve swings upward, reaching a value of \$27.8/Mg at the 540 Mg/hour capacity. This behavior indicates a negative economy of scale with respect to plant size.

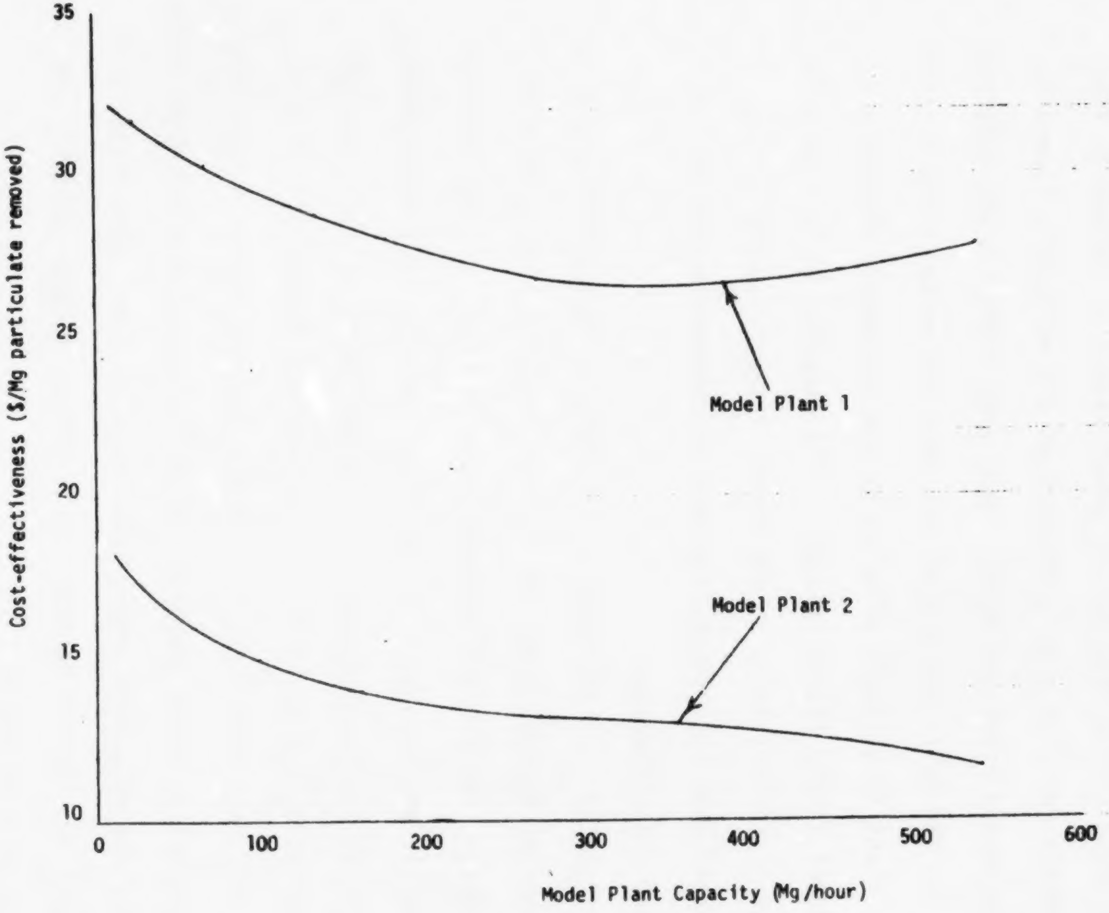


Figure 8-1. Cost-Effectiveness of Alternative Control Systems.

The following explanation can be offered for this anomaly. First of all, the fabric filter costs represented by Figure 8-1 are functions of the gas volumetric flowrate, not the plant capacity. Secondly, the cost-effectiveness ratio is also a function of the volumetric flowrate, as well as the annual operating hours. Now, when a model plant consists of more than one fabric filter system, the mean cost-effectiveness ratio for the model plant is strongly affected by the volumetric flowrates of the individual fabric filter systems. (The equation in Section 8.2.2 bears this out.) For instance, if one fabric filter flowrate is much smaller or larger than the others, the mean cost-effectiveness will be weighted toward that flowrate.

Such a situation is illustrated by the data in Tables 8-25 and 8-26, for the 270 and 540 Mg/hour model plants, respectively. In Table 8-25, data for two fabric filters are presented, one of which is sized for five times the flowrate as the other. Accordingly, the mean cost-effectiveness ($26.7/Mg) is heavily weighted toward the larger fabric filter. But with the 540 Mg/hour model plant (Table 8-26), there are three fabric filters, sized at 255, 877, and 906 m^3/min. Since two of these fabric filters are approximately equal in size, the mean cost-effectiveness for the model plant ($27.8/Mg) is weighted toward them. Note, moreover, that this ratio is higher than that for the 270 Mg/hour plant. This, in turn, accounts for the dip in the curve in Figure 8-1.

8.2.5 Control Cost Comparison

Before the accuracy and representativeness of model plant control costs can be ascertained, they must be compared with costs obtained from

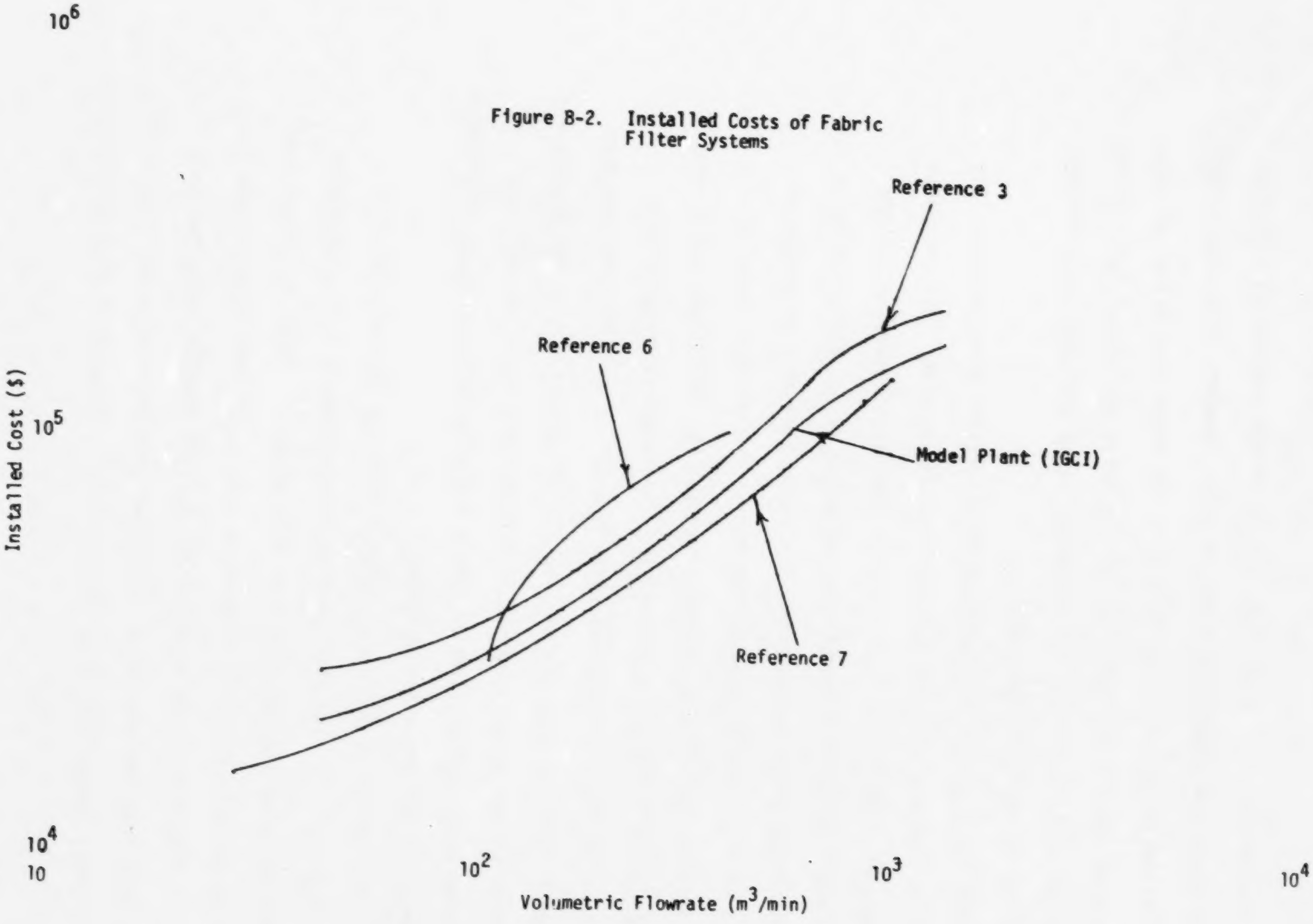


Figure 8-2. Installed Costs of Fabric Filter Systems

other data sources. In doing this, one can either compare the installed capital costs, the annualized costs, or both. However, since the capital costs influence the annualized costs (via the annualized capital charges), and because there is much more variability among the several terms in the annualized cost (utilities, for instance), it is preferable to limit the comparison to the installed costs.

Even for a control system sized for a specific emission point, the installed cost may vary considerably from site-to-site. Such things as the cost of installation labor (electricians, pipefitters, etc.), the requirement for special installation materials (e.g., extra insulation for systems installed in colder climates), and the presence or absence of excess utility capacity considerably influence the total installed cost.

Keeping this in mind, however, capital cost comparisons can be made, among a range of control system sizes. This comparison may be made graphically; that is, installed costs adjusted to the same reference date (December 1976, in this case) can be plotted against some technical parameter relevant to the control system. In this section, installed costs are compared among various sizes of fabric filter systems, using gas volumetric flowrate as the comparison parameter.

The model plant costs are compared with cost data obtained from industry sources[6,7] and with costs developed in-house from a compendium of air pollution control costs (the GARD Manual).[3] These costs have been plotted against volumetric flowrate on full logarithmic paper (Figure 8-2). For all flowrates in the domain of 42 to 1,400 actual m^3/min, the costs developed from the GARD Manual are higher than the model plant costs. The discrepancy ranges from 17 to 32 percent, the higher difference corresponding to 42 m^3/min. The cost curve for reference 6 intersects the model plant curve at 115 m^3/min. (This is approximately the size of the grinding operation baghouse in the 9.1 Mg/hour model plant.) Below this flowrate the reference 6 costs are lower; above it, they are higher, but by no more than 53 percent. The last fabric filter cost curve (reference 7) lies consistently below the model plant curve for all flowrates between 28 and 1,050 m^3/min. However, the differences between the costs--7 to 18 percent--are not significant.

All in all, the model plant fabric filter costs compare reasonably well with the data supplied by references 3, 6, and 7.

8.3 OTHER COST CONSIDERATIONS

As discussed in Section 8.2, it is unlikely that non-metallic minerals plants covered under the anticipated NSPS would be required to monitor the opacity of their particulate emissions. Nonetheless, for the benefit of those plants considering an opacity monitoring program, costs are presented for these devices in this section.

Continuous monitoring of opacity usually involves the use of a transmissometer installed in a fabric filter stack. This instrument relates the transmittance of a light beam across the stack to the opacity of the exhaust . These devices are fully automatic and usually require only periodic maintenance. (However, manual stack testing may be required for calibration of the instrument.)

Table 8-35 lists costs for a typical opacity monitoring system obtained from an instrument vendor.[8] The system shown consists of a visible emission monitor, controls, data readout-converter, strip chart recorder, and other auxiliaries. Of the $20,000 installed cost, half is the equipment purchase cost, the other $10,000 is for installation. It has been assumed that no scaffolding would have to be erected on the stack being monitored. However, if scaffolding is required, the installation cost could increase appreciably. The scaffolding cost would, as expected, vary from site to site. For instance, the cost of scaffolding a 50-foot "stub" stack (the kind normally used with nonmetallic minerals plant fabric filters) would be $20,000 to $30,000.

Table 8-35. MONITORING COSTS FOR NON-METALLIC MINERALS MODEL PLANTS[a,b]

Parameter	Value	
Operating factor, hours/year	2000	8400
Installed capital cost, M$	20	20
Direct operating cost, M$/year	0.7	1.0
Annualized capital charges, M$/year	4.1	4.1
Total annualized cost, $/year	4.8	5.1

[a] Reference 8.

[b] These costs are for opacity monitoring of one stack. No scaffolding costs are included.

[c] The letter "M" denotes thousands; "MM" denotes millions, etc.

The direct operating costs have been computed at the 2000 and 8400 hours/year operating factors. Here, the only cost sensitive to a change in the operating factor is the electric power cost. At the lower operating factor (corresponding to the crushing model plant) the power cost is $100/year against $420/year at 8400 hours/year of operation. The rest of the direct operating cost is for maintenance of the monitoring system, which amounts to 3 percent of the installed cost.

The annualized capital changes have been computed assuming a ten-year life and a ten percent annual interest rate, plus four percent of the installed cost for taxes, insurance, and administrative charges. Depending on the operating factor, the total annualized cost is either $4,800 or $5,100 per year.

For the smaller model plants, these amounts are appreciable--one-third of the fabric filter total annualized costs at the 9.1 Mg/hour Model Plant 1. However, with the larger plants, more than one baghouse would need to be monitored. Thus, their monitoring costs could be two or more times the costs in Table 8-35. In other words, there is little or no economy of scale in the costs for monitoring multiple stacks. This is so because each stack requires separate opacity instrumentation, scaffolding, and other equipment. The only savings would result from some parts of the installation cost, such as engineering. But these latter costs, when taken together, generally comprise only a small fraction of the installed cost.

References for Sections 8.2 and 8.3

1. Written communications between William M. Vatavuk (Economic Analysis Branch, Strategies and Air Standards Division) and James A. Eddinger, (Industrial Studies Branch, Emission Standards and Engineering Division). Dates: August 18, 1976; June 15, June 30, July 8, 1977; and February 9, March 17, and April 20, 1978.

2. Nonmetallic Minerals Industries Control Equipment Costs. Prepared by: Industrial Gas Cleaning Institute (Stamford, Connecticut). Prepared for: U.S. Environmental Protection Agency, Strategies and Air Standards Division, Economic Analysis Branch (Research Triangle Park, North Carolina). Contract No. 68-02-1473, Task No. 19. February 1977.

3. Kinkley, M.L. and R.B. Neveril. Capital and Operating Costs of Selected Air Pollution Control Systems. Prepared by: GARD, Inc. (Niles, Illinois). Prepared for: U.S. Environmental Protection Agency Strategies and Air Standards Division, Economic Analysis Branch (Research Triangle Park, North Carolina). Contract No. 68-02-2072. May 1976.

4. McGlamery, G.G., et al. Detailed Cost Estimates for Advanced Effluent Desulfurization Processes. Prepared by: Tennessee Valley Authority, Muscle Shoals, Alabama, under Interagency Agreement EPA IAG-134(D) Part A. Prepared for: Office of Research and Development, U.S. Environmental Protection Agency, Washington, D.C. January 1975.

5. Written communication between William M. Vatavuk (U.S. Environmental Protection Agency, Strategies and Air Standards Division, Economic Analysis Branch, Research Triangle Park, North Carolina) and Sidney Orem (Industrial Gas Cleaning Institute, Stamford, Connecticut). Date: June 15, 1977.

6. Written communications between F.J. Rogers (Gypsum Association, Evanston, Illinois) and William M. Vatavuk (U.S. Environmental Protection Agency, Strategies and Air Standards Division, Economic Analysis Branch, Research Triangle Park, North Carolina). Dates: April 29, May 11, and July 27, 1977.

7. Written communication between William M. Vatavuk (U.S. Environmental Protection Agency, Strategies and Air Standards Division, Economic Analysis Branch, Research Triangle Park, North Carolina) and Curtis Hamilton (Englehard Minerals and Chemicals, Attapulgas, Georgia). Date: January 18, 1978.

8. Written communication between William M. Vatavuk (U.S. Environmental Protection Agency, Strategies and Air Standards Division, Research Triangle Park, North Carolina) and Ronald Zweben (Lear Siegler, Inc., Raleigh, North Carolina). Date: April 26, 1978.

8.4 ECONOMIC IMPACT ASSESSMENT

8.4.1 Introduction

The non-metallic mineral industries crush, size, and in some cases grind material extracted from the ground. The resultant output is generally used as an intermediate product in such activities as highway or building construction.

Although the 18 non-metallic mineral industries considered in this economic impact assessment have similar production and marketing characteristics, there are distinct differences among them. Although these minerals must be extracted from the ground, the particular method used for extraction depends on the hardness of the mineral and the geological deposit in which it is found. For example, stone must generally be extracted by blasting with dynamite, while sand can be extracted with only power shovels. The harder minerals are first broken with drop balls and transported by truck to the crushing plant immediately following extraction.

As described in Section 3.2, most minerals then go through a number of crushing steps in order to produce the requisite size material for the purposes of the customer. This stage includes primary and secondary crushing and, in some cases, tertiary crushing. In each crushing stage the material is further reduced to a smaller size classification. These crushing stages are important in producing material meeting the quality specifications of the application. For some minerals; e.g., clay, dryers are interposed between the various crushing stages to extract the moisture found in the material. Other minerals such as stone and pumice do not require dryers, while still other materials, such as sand, can be extracted and processed in a wet form.

For many minerals the final crushing stage produces an output which can be sold for various purposes; e.g., stone, and sand and gravel used as a highway or concrete aggregate. Other materials must be further reduced in size in a grinding mill before they are acceptable in product applications; e.g., clay which is to be expanded and gypsum used as a retarder in cement production.

In short, non-metallic minerals are basically processed in the same manner, but there are production distinctions which the following economic impact analysis will address.

As Section 8.1 shows, non-metallic minerals have wide price differentials. Even within a particular mineral, there are signifcant variations in price depending on product application. The prices of non-metallic minerals range from $2/ton for sand gravel to $250/ton for high grade talc. Most non-metallic minerals have regional markets. In general, the lower the value of the mineral, the shorter is the distance that the material travels to a customer. For example, stone, and sand and gravel, lower price minerals, generally are not transported over 30 miles from the plant. At this distance the f.o.b. plant price of the material is approximately doubled by transportation costs. Therefore, transportation costs limit the geographic area of competition for many non-metallic minerals and competition between and among minerals is localized.

Ownership characteristics differ between the non-metallic minerals industries. Stone quarrying and crushing is done primarily by privately held companies which may have other business ventures requiring stone; e.g., highway construction or concrete manufacturing. Gypsum, on the other hand, is generally produced by diversified, publicly held companies in the building and construction materials industry who have integrated backwards to the mine. Publicly held companies, diversified into many other activities, though, are in general the largest producers in the industries.

In the analysis which follows, each new non-metallic mineral plant will be assessed as if it stands alone; i.e., the plant is not associated with any other business activity nor is it associated with any larger parent company. This assumption has the effect of insulating the control cost impact to the plant in question which must then support the control cost without any assistance from other business activities or firms.

The impact which will be assessed is the effect of the incremental cost of NSPS control on both:

- "Grassroots" new plants
- Expansions of existing plants.

The effect to be determined is the feasibility of these two investments, and therefore, the potential for new and expanded plant construction with the superimposed NSPS costs on each investment.

Incremental NSPS control costs are costs over and above those control costs required to meet state implementation plan (SIP) standards. Since each state has particulate emission control standards, any new plant or reconstructed/modified plant would have to meet SIP standards in the absence of the NSPS. Incremental costs are the difference between the costs associated with NSPS control and SIP control. In this analysis SIP costs are assumed to be non-existent, and therefore incremental costs are the total of NSPS costs. Though SIP costs are not zero in the real world, this assumption is used in order to provide a conservative analysis for evaluating economic impacts.

This section is organized in three parts. Section 8.4.2 will develop the methodological procedure utilized to estimate the economic impact. Section 8.4.3 will present the findings of this analysis and Section 8.5 will show the total industry costs of the promulgation of NSPS.

8.4.2 Methodology

This section will describe the methodology used to measure the economic impact on the non-metallic mineral industries.

The economic impact is evaluated by developing model plants based on historical characteristics in the non-metallic mineral industries. As will be seen, these characteristics include production capabilities, asset size and other financial characteristics. The models do not represent any particular plant as any individual plant will differ in one or more of these characteristics. The models are meant to provide an indication of the degree of impact on all plants in a particular industry by incorporating in the model the major characteristics prevailing in each segment of the non-metallic mineral industry.

Two control cost models have been constructed for the 18 non-metallic mineral industries, as seen in Section 6.

- Model 1 - those industries which generally only crush the mineral
- Model 2 - those industries which generally both crush and grind the mineral

In addition, the portable crushing plant model segments of the crushed stone, and sand and gravel industries are discussed in Supplement A.

Each industry has been further disaggregated by typical model plant sizes to account for size variations within each industry. Typical plant sizes for each mineral are shown in Section 6. Although industry representatives and equipment suppliers do not expect 9 Mg/hr (10 tons/hr), 23 Mg/hr (25 tons/hr) and 68 Mg/hr (75 tons/hr) plants in the crushed stone, and sand and gravel industries to be constructed in the future, they were, nevertheless, analyzed because they have historically represented the majority of plants in the industries.

Only minerals represented by model 2 are assumed to be in need of expansion investment in the near future. Expansion will consist of 4.5 Mg/hr (approximately 5 tph) and 9.1 Mg/hr (10 tph) grinding mills.

Expansion of existing plants represented by model 1 is not considered because it is expected that they will need to invest in capital expansion to meet increased demand only on a sporadic basis. Reconstruction/modification of existing plants is also not considered; first, because routine replacement of worn out equipment will not subject them to the NSPS; and second,because such replacement is expected to occur at a very slow pace since the production life of most processing equipment is on the order of 20 to 30 years.

The first step in the analysis consisted of screening each of the 18 minerals by ranking the potential product price effects of the incremental control cost. Those minerals with the potentially highest product price impact were then considered for further evaluation.

The next step in the analysis established the scenario under which the plant would operate. This scenario consisted of four elements:

- the total of NSPS control costs were incremental costs; i.e., that there are no SIP control costs that a plant would have to incur in the absence of NSPS control.

- the production volume is constant throughout the life of the project except for the crushed stone plant where it is assumed that they operate at 50% of capacity for the first year.
- NSPS control cost pass through is limited by competition of existing plants in the same industry which do not have to meet the NSPS.
- the new plant operates as a separate business entity and cannot expect to finance the control from another business activity or parent firm.

Because of technical constraints in establishing a new quarrying operation in the crushed stone industry, which constraints are not as severe in the other industries, the crushed stone crushing plant is assumed to operate at 50% of capacity during the first year.

The plant is assumed not to be dependent on any other business venture. Therefore for new plants the NSPS control cost is not allocated or spread over any operation except production of the affected facility which is the new plant. Financing of the equipment can only be made from the expected revenues of the new plant and from no other business venture. For expanded plants a portion of the annualized control cost was assumed to be absorbed by the existing plant which is being expanded.

Substitutability between many of the non-metallic minerals in many product applications prevails in the market. Because of the variations in control cost per ton between the minerals, the potential price increase of any mineral should be expected to equal the cost pass through portion of the nearest available mineral substitute with the lowest control cost per ton. If a new plant of one mineral was being constructed in the same geographical competitive area as a new plant of another mineral and both were perfect substitutes for each other, then the cost pass through would likely be the control cost of the less affected mineral. A more conservative analysis is where a new plant of a mineral is constructed in the same geographically competitive area as existing plants of the same mineral. The existing plants would not experience any NSPS standard and therefore, cost, and the new plant would have to compete with this existing plant. The new plant would not be a major supplier of the mineral in the area and would not be able to control the price. Therefore, this new plant would have to completely absorb the control cost. But as demand grew for the mineral, additional new plants would be required and/or, in the case of gypsum and clay, older plants would have to expand to meet the increased demand. This condition would bring an increasingly larger segment of the mineral supply market under NSPS control. Therefore, it is likely that new plants will be able to pass through the control cost gradually over the years. This is reflected in our assumption that 25 percent of the control cost is passed through every 4 years (alternatively every 4 years 25 percent less of the cost is absorbed). This is the premise which is used in the succeeding discounted cash flow (DCF) analysis.

Each plant size of each of the potentially significantly affected minerals was then analyzed by using a discounted cash flow analysis (DCF). DCF is an investment decision technique which provides information on the economic feasibility of a potential capital investment. It measures the discounted cash inflows over the life of the investment and compares them to the discounted cash outflows. If the sum of the discounted cash inflows is equal to or greater than the sum of the discounted cash outflows, the investment is feasible from the firm's point of view. If the sum of the discounted cash inflows is less than the sum of the discounted cash outflows, the investment is not feasible from the firm's point of view. In order to take into consideration the time value of money, all cash flows must be discounted to the present by use of an appropriate discount factor. This is necessary to bring all cash flows to a comparable present day basis for comparison.

Four data elements are required to complete the analysis:

- Expected life of the investment
- Cash flows to be discounted
- Weighted average cost of capital
- Total plant investment.

The expected life of the investment was taken to be 20 years although the expected life of the major pieces of equipment can range from 20 to 30 years. The cash flows are discounted and summed over a 20 year period.

Any potential capital investment will generate cash flows in the form of new earnings, and depreciation. These flows are discounted by the weighted average cost of capital discount factors, summed, and compared to capital outlays to determine the economic feasibility of the potential investment. In the analysis to be presented in the following section the incremental NSPS control costs are superimposed on this model to determine their effect on cash flow and the decision to invest in a new "grassroots" or expanded plant for each size plant in each of the affected non-metallic mineral industries identified for further analysis.

The cash flows which are considered are:

1. Net earnings before interest and after tax.
2. Depreciation of the plant including control equipment.
3. Depletion.
4. Working capital recovery.
5. Plant and control equipment investment.

For each year cash inflows 1 through 4 are added (working capital recovery occurs only at the end of the life of the investment, the 20th year). This resultant annual sum is discounted and the annual discounted sums are totalled over the 20 year period. This new sum is compared to the discounted sum of the total investment including NSPS control investment. If the sum of the discounted cash inflows 1 through 4 is larger than the discounted sum of cash outflow 5, the investment is economically feasible even after the requirement of NSPS controls.

That an investment is found to be economically feasible does not necessarily mean that the investment will be made by any individual firm. Other forces or market concerns important to the company such as the desire to diversify into other industries, or desire to expand through acquisitions may preclude the new plant investment from being made.

The discount factors which are used to discount these flows are determined by solving $1/(1 + i)^n$ where i is the weighted average cost of capital and n is the year from the beginning of the project. In this case n is from 1 to 20. For each year of the 20 year investment span a different discount factor is generated. Each year's discounted cash flow shows the present value of that cash flow. The cost of capital is the weighted average financing expense of an investment that is financed partly through debt and partly through equity.

Total plant investment was determined by the equipment needed for quarrying, crushing, and, if appropriate, drying and grinding the mineral, and added to the required NSPS control equipment capital cost developed in Section 8.2 and working capital requirements.

8.4.2.1 Critical Elements

The following list provides the major critical elements of the analysis for the significantly impacted industries:

- Control cost absorption is 25 percent less every 4 years.
- Maintenance expenditures over the life of the equipment equal salvage value of the equipment.
- The profit rate for new plants is the same as existing plants.
- All stationary plant equipment has a 20 year life with the exception of rolling stock which has a 7 year life.
- 8,400 hours of operation per year is assumed for plants with grinding capacity.
- Cost of debt capital is 3 percent above the prime rate of 7 percent in 1976.
- The total investment is financed 30 percent by debt and 70 percent by equity capital.
- Weighted average cost of capital is 11.8 percent.
- The debt financing maturity is 10 years for stationary plants and control investment and 7 years for rolling stock.
- Rolling stock is 77.7 percent of quarry investment.

Maintenance expenditures are a cash outflow over the life of the equipment while the salvage value of the equipment is a cash inflow at the time of sale. No estimates of maintenance expenditures were found during this analysis. Salvage value of equipment generally runs from 25 to 30 percent of the original cost. Since maintenance expenditures are a negative cash flow and salvage value a positive cash flow and since salvage value at the time of sale should be related to the amount of maintenance put into the equipment it is assumed that they are equal and counterbalance each other.

The profit rate on the new plant is assumed to be equal to an existing plant although profit rates between a new and existing plant will differ due to unique tax consequences and differences in technological efficiencies. It is felt that these two effects counterbalance each other sufficiently for the purpose of this analysis.

The plant has a useful life of 20 years. Equipment life varies among the pieces of equipment used in the non-metallic mineral industry, but, on average, the plant has a 20 year life. In the analysis some account has been given to this aspect by separating "rolling stock" (mineral transport vehicles) from stationary stock equipment and ascribing a 7 year life to the rolling stock.

In those industries with grinding capacity, 8,400 hours of operation is used to generate sales volume and revenue based on information supplied by industry.

Industry representatives have stated that generally an investment can be financed at 2 to 3% above the prime rate. A 3% above prime rate was utilized to reflect a conservative analysis.

A weighted average cost of capital for the mining industry as a whole of 11.8% and debt/equity financing of 30/70% is given by Dr. Gerald Pogue (Section 8.4.2.2). To the extent that particular non-metallic mineral industries within the mining category experience a cost of capital of more or less than 11.8%, the discounted cash flows will be different.

8.4.2.2 Data Sources

The following list provides the data sources for various aspects of the analysis:

• Average Selling Price	- Bureau of Mines
• Profit Rates	- Robert Morris Associates - Industry Representatives - Annual Reports
• Working Capital	- Robert Morris Associates
• Plant Investment	- Barber-Green Co. - Kennedy Von Saun Co. - C. E. Raymond - Combustion Engineering Inc.
• Cost of Debt Capital	- Federal Reserve Bank - Industry Representatives
• Cost of Capital, Debt to Equity Ratio	- "Estimation of the Cost of Capital for Major U.S. Industries with Application to Pollution Control Investments", Dr. Gerald A. Pogue, 1975.
• NSPS Control Costs, Sizes and Operating Hours	- Chapter 8.2

- Depreciation Schedules - Equipment Suppliers
- Investment Tax Credit, Depletion Allowance - Internal Revenue Code
- Expected Life of Equipment - "Background Information for the Non-Metallic Minerals Industry," Vol. I, PEDCO Environmental Specialists.

8.4.3 Screening Analysis

The first step in the analysis was to assess the effect on the 18 non-metallic mineral industries of NSPS control costs based on the ratio of control cost per ton to price per ton. This ratio represents annualized cost per ton as percent of average price. Table 8-36 presents the results of this analysis.

Table 8-36 shows 23 entries because clay has been disaggregated into 6 distinct categories. For both those industries that fall under the Model 1 classification (crushing only) and Model 2 classification (crushing and grinding) the impact is shown by dividing the annualized operating and capital costs for control of the smallest size plant specified in Table 6.3 by the annual revenue of the mineral.

Because control costs per ton of mineral output are larger for the smallest plant compared to the largest plant, this procedure inflates the impact. Since large plants dominate the production in most industries, average industry impact based on this ratio would be substantially lower. Average industry impact is shown in section 8.5. Table 8-36 is not meant to show industry impact but to be used as "worst case" screening method to ascertain industries requiring further study.

Table 8-36

RANK ORDER OF INDUSTRIES
WITH HIGHEST CONTROL COST IMPACT

Industry	Rank	Control Cost/Ton Price/Ton[1]	
Pumice	1	28.0%	
Sand and Gravel	2	15.8	
Crushed Stone	3	13.4	Candidates
Common Clay	4	11.7	for further
Gypsum	5	5.0	evaluation
Perlite	6	4.1	
Fire Clay	7	2.0	
Bentonite	9	1.4	
Ball Clay	10	1.3	
Salt	11	1.2	
Barite	12	1.1	
Feldspar	13	1.1	
Fuller's Earth	14	.6	
Mica	14	.6	
Kaolin	14	.6	
Talc	17	.4	
Kyanite	18	.3	
Vermiculite	18	.3	
Fluorspar	18	.3	
Diatomite	18	.3	
Sodium Compounds	22	.2	
Boron	23	.1	
Gilsonite	25	-(2)	

---

(1) Based on smallest model size in industry.

(2) No price available - only 1 company producing approximately 100,000 tpy.

Any industry where the per ton control cost was larger than 2% of the average price was considered to be potentially significantly impacted and worthy of further evaluation. Two percent was taken to be the cut-off point because this rate, even in the worst case situations, is considerably lower than the 5% industry average rate which is the EPA guideline for assessing major economic impact. The minerals considered to be potentially significantly impacted are pumice, sand and gravel, crushed stone, common clay, gypsum, and perlite.

Perlite, gypsum and pumice have three stationary model plant sizes: 9, 23 and 68 Mg/hr (10, 25 and 75 tph). Common clay has four; 9, 23, 68 and 136 Mg/hr (10, 25, 75 and 150 tph). Both sand and gravel, and crushed stone have six stationary model plant sizes, 9, 23, 68, 136, 272 and 544 Mg/hr (10, 25, 75, 150, 300 and 600 tph). The portable plant segments of the crushed stone, and sand and gravel industries are discussed in Supplement A.

Each of the six remaining potentially significantly affected minerals were then compared on the basis of relative prices, and the effect of control costs on relative prices of the minerals, taking into account the product substitutability among them. This analysis showed that the "worst case" situation was a new plant of any mineral competing with an existing plant of the same mineral. For each mineral, a baseline relative price was computed. This relative price was the ratio of the price of each mineral to the price of each of the other minerals prior to NSPS control costs. This baseline relative price ratio was then compared to the "worst case" situation after the imposition of control costs, assuming all control costs were passed through. The "worst case" situation was the smallest size plant of any mineral compared to the largest size plant of the remaining minerals since control costs per ton of output are larger for smaller plants. A decline in this ratio, price of other minerals after control divided by the price of this mineral after control, indicates that other minerals are becoming less expensive relative to this mineral and that demand should significantly shift away from this mineral if the cross-elasticity of demand is high.[1] Cross-elasticity of demand is dependent on the minerals having acceptable substitutability potential. The substitutability potential was evaluated by comparing the mineral of interest to the two minerals having the largest changes in relative prices. In each case substitutability potential was rated only low to moderate because of the product quality differences between the minerals and the geographical separation of deposits of different minerals. For this reason the more conservative scenario, a new plant of any mineral competing with an existing plant of the same mineral, was employed in the analysis.

8.4.4 Plant Investment

Grassroots Plants

Investment costs were gathered for quarrying, crushing, and where appropriate, drying and grinding equipment from equipment suppliers. Tables 8-37 and 8-38 show the total investment costs for each size plant studied in each industry. For all plant sizes smaller than 136 Mg/hr (150 tph), quarrying and crushing plant costs were derived by use of the engineering 0.6 power capacity rule. For the quarrying operation, rolling stock was

---

[1] Cross-elasticity of demand is the percentage change in the quantity of one product divided by the percentage change in price of another product.

Table 8-37

PLANT INVESTMENT COSTS[1]

(in thousands of dollars)

Industry	Size Mg/hr (tph) 9 (10)	23 (25)	68 (75)	136 (150)	272 (300)	544 (600)
Pumice	$269.9	$ 410.4	$ 740.3	N.A.	N.A.	N.A.
Sand & Gravel	236.9	374.4	693.2	$1,034.6	$2,036.1	$3,986.7
Crushed Stone	251.1	399.6	742.9	1,139.0	2,188.6	4,291.4
Common Clay	817.4	1,282.3	2,160.4	3,118.1	N.A.	N.A.
Gypsum	664.9	1,058.3	1,850.2	N.A.	N.A.	N.A.
Perlite	555.3	822.2	1,654.1	N.A.	N.A.	N.A.

---

[1] Includes NSPS control capital costs and working capital.

[N.A.] Not Applicable because plants of this size are not likely to be constructed in the absence of a NSPS.

Table 8-38

EXPANSION INVESTMENT COSTS[1]

(in thousands of dollars)

Industry	Size Mg/hr (tph) 4.5 (5)	9 (10)
Common Clay	$288.1	$421.1
Gypsum	292.9	430.7

---

[1] Includes NSPS control costs and working capital.

separated from stationary stock by factoring total quarry investment cost by 0.777.[1] All plant investment costs were deflated to fourth quarter, 1976 prices in order to make investment consistent with the derivation of sales revenue which is based on fourth quarter, 1976 average selling prices. The investment deflator was calculated from the Chemical Engineering equipment cost index.

Once total plant investment was calculated and separated into stationary plant equipment and rolling stock, NSPS control cost investment and working capital were added to stationary stock investment. The debt portion of the stationary stock investment was derived by using a 0.3 factor specified by the Dr. Gerald Pogue study; i.e., 30% of investment financed by the bank and 70% from the investor's own funds, equity. Bank financing for stationary stock debt was taken by 10%, 10 years, giving a capital recovery factor (CRF) of 0.16275. These industries are usually able to receive financing at 2 to 3% above the prime rate. In 1976 the prime rate was approximately 7%. The debt portion of rolling stock investment was also established by using a 0.3 factor. The rolling stock was assumed to be financed at 10% over the useful life of the stock, 7 years. The CRF is 0.20541. Subsequent purchase of new rolling stock to replace original rolling stock was assumed to occur at the same price. For both stationary and rolling stock, the annual principal and interest payment were calculated.

---

[1] Derived from "The Crushed Stone Industry: Industry Characterization and Alternative Emission Control Systems", Arthur D. Little, Inc. where rolling stock equals 77.7% of total quarry plant costs.

Expansion Plants

Investment costs for expansions consisted of 4.5 Mg/hr (5 tph) and 9 Mg/hr (10 tph) grinding mill costs for the clay and gypsum industries only. These investment costs are shown in Table 8-38. Debt financing was 30% of total investment at 10% over 10 years.

8.4.5 Discounted Cash Flow Analysis

Table 8-39 which shows an analysis for construction of a new 136 Mg/hr (150 tph) crushed stone plant is an example of the data sheets which were developed for each of the plant sizes for each of the six potentially significantly impacted industries. The steps in the DCF analysis will be described below using this example and referring to row entries in Table 8-39.

- Row 1, revenue, was generated by multiplying hours of operation by tons per hour of output and by the average F.O.B. plant selling price of the output. This revenue estimate was assumed constant for each year of the life of the investment. For stationary crushed stone plants, the plant was taken to operate at 50% of capacity the first year as related by industry representatives. Control equipment was assumed to be operating at 100 percent, and therefore control operating costs are 100 percent.
- Row 3, interest including control, was determined by calculating the principal and interest repayment schedule for the plant investment without control investment.
- Row 4, earnings before interest and tax, was derived by multiplying revenue by the before tax profit rate of row 2 and adding back the interest of row 3.

TABLE 8-39 DISCOUNTED CASH FLOW ANALYSES CRUSHED STONE PLANT 136 Mg/hr (150 tph) (IN THOUSANDS OF DOLLARS)

		1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	Revenue	$357.5	$705.5	$705.5	$705.5	$705.5	$705.5	$705.5	$705.5	$705.5	$705.5
2	Profit rate before tax	9.0%	9.0%	9.0%	9.0%	9.0%	9.0%	9.0%	9.0%	9.0%	9.0%
3	Interest excluding control	28.7	27.4	24.9	22.2	18.7	16.8	17.1	17.7	14.2	10.4
4	Earnings before interest and tax	61.4	90.9	88.4	86.7	82.2	79.3	75.6	81.2	77.7	73.9
5	Annualized control cost	27.8	27.5	27.2	26.9	26.6	26.2	25.8	25.4	24.9	24.4
6	Control Cost Absorbed	All	All	All	All	20.	19.7	19.4	19.1	12.5	12.2
7	Control Interest	3.7	3.4	3.1	2.8	2.5	2.1	1.7	1.3	.8	.3
8	Net earnings before interest and after control	37.3	66.8	64.3	61.6	64.7	61.7	57.9	63.4	66.	67
9	Federal tax liability (also considering interest)	.8	7.4	7.5	7.6	9.1	9.1	9.2	9.3	11.0	11.1
10	Investment tax credit	.8	7.4	7.5	7.6	9.1	9.1	9.2	9.3	11.0	11.1
11	Federal tax liability after credit	0	0	0	0	0	0	0	0	0	0
12	Minimum tax	0	1.2	1.2	1.2	1.7	1.7	1.7	1.7	2.3	2.3
13	State tax	.2	1.8	1.8	1.8	2.2	2.2	2.2	2.2	2.6	2.6
14	Net earnings before interest, after credit, control & tax	37.1	63.8	61.3	58.6	60.8	57.0	54	59.5	61.1	57.1
15	Depreciation of stationary stock	64.1	64.1	64.1	64.1	64.1	64.1	64.1	64.1	64.1	64.1
16	Depreciation of rolling stock	45.6	45.6	45.6	45.6	45.6	45.6	45.6	45.6	45.6	45.6
17	Depreciation of control equipment	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2
18	Depletion 5%	2.	18.	18.2	18.4	21.7	21.9	22.0	22.2	25.5	25.6
19	Working capital recovery										
20	Cash inflow	161.	203.7	201.4	198.9	204.4	201.6	197.9	203.6	208.5	204.6
21	Discount factor	.8945	80	.7156	.64	.5725	.512	458	.4097	3665	.3278
22	Discounted cash inflow	144.	163.	144.1	127.3	117.	103.2	90.6	83.4	76.4	67.1
23	Cash outflow 1111.0								326		
24	Discounted cash outflow 1111.0								131		

		1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1	Revenue	$705.5	$705.5	$705.5	$705.5	$705.5	$705.5	$705.5	$705.5	$705.5	$705.5
2	Profit rate before tax	9.0%	9.0%	9.0%	9.0%	9.0%	9.0%	9.0%	9.0%	9.0%	9.0%
3	Interest excluding control	6.3	4.5	3.4	1.8	9.6	8.6	7.5	6.3	4.5	3.4
4	Earnings before interest and tax	69.8	68	66.9	65.3	73.1	72.1	71	69.8	68	66.9
5	Annualized control cost	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9
6	Control Cost Absorbed	0	0	0	0	0	0	0	0	0	0
7	Control Interest	0	0	0	0	0	0	0	0	0	0
8	Net earnings before interest and after control	69.8	68	66.9	65.3	73.1	72.1	71	69.8	68	66.9
9	Federal tax liability (also considering interest)	16.5	17	17	17	17	17	17	17	17	17
10	Investment tax credit	9.9	0	0	0	17	15.0	0	0	0	0
11	Federal tax liability after credit	6.6	17	17	17	0	2	17	17	17	17
12	Minimum tax	2.3	2.3	2.3	2.3	3.3	3.3	2.2	2.2	2.1	2.2
13	State tax	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
14	Net earnings before interest, after credit, control & tax	57.7	45.5	44.4	42.8	66.6	61.6	48.6	47.4	45.6	44.5
15	Depreciation of stationary stock	0	0	0	0	0	0	0	0	0	0
16	Depreciation of rolling stock	45.6	45.6	45.6	45.6	45.6	45.6	45.6	45.6	45.6	45.6
17	Depreciation of control equipment	0	0	0	0	0	0	0	0	0	0
18	Depletion 5%	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8
19	Working capital recovery										28.2
20	Cash inflow	135.1	122.9	171.8	120.2	144	141	126	124.8	123	150.1
21	Discount factor	2931	2622	.2346	.2098	.1877	.1679	1501	.1343	.1201	.1074
22	Discounted cash inflow	39.7	32.2	28.5	25.2	27	23.7	18.9	16.8	14.8	16.1
23	Cash outflow 1111.0					326					
24	Discounted cash outflow 1111.0					60					

Total Discounted Cash Inflow 1359

Total Discounted Cash Outflow 1302.0

8-110

Reproduced from best available copy.

- Row 5 shows the NSPS annualized control costs for each year. Since depreciation for control equipment was taken to be straight line over 10 years, the years from 1987 onward show only annual operating costs.
- Row 6, control cost absorbed, reflects the scenario mentioned in Section 8.4.2, methodology. For the first 4 years all control cost is assumed to be absorbed because the plant is competing with existing established plants which have no NSPS costs. Therefore, the new plant must absorb the entire cost. In the years 1981 to 1985 the plants must absorb 75% of the cost and can pass through 25% because other new plants are being established. New plants must, then, meet NSPS costs. For each succeeding 4 year period, the plant absorbs 25% less of the original cost.[1] Since in the year 1987 total operating costs are less than control cost absorbed in 1986, all operating costs are assumed to be passed through in the years from 1987 to 1996.
- Row 7, control interest, was derived by calculating the principal and interest repayment schedule for the NSPS control investment.

---

[1] The increased revenue from cost pass through is not shown since we are only interested in the effect of cost absorption on net earnings.

- Row 8, net earnings before interest and after control, shows the effect of NSPS absorbed control costs on the earnings potential of the plant. Absorbed control costs are subtracted from Row 4 and control interest of Row 7 is added back. Adding back of interest is required in the model because the discount factors taken into consideration the repayment of the loan.
- Row 9, federal tax liability, is derived by multiplying net earnings after control by the appropriate marginal tax rates.
- Row 10, investment tax credit, considers the effect of the 10% investment tax credit on the tax liability of the plant.

  (The investment tax credit can be carried forward 7 years or until 10% of the investment is credited, whichever comes first. The tax credit cannot be greater than tax liability and for tax liabilities over $25,000 the credit is calculated as $25,000 plus 50% of the liability over $25,000. For example, in year 1977 tax liability is $800, therefore, the credit is $800 since the credit cannot be greater than tax liability. In year 1978 the same reasoning applies. If tax liability had been $30,000, then the credit would have been $25,000 + (0.5) $5,000 or $27,500.
- Row 11, federal tax liability after credit, is tax liability minus the investment tax credit.
- Row 12, minimum tax, shows the 15% minimum tax on tax preference items. In this analysis the only tax preference item is the depletion allowance.
- Row 13, state tax, is assumed to be 5% of net earnings. The 5% rate is the most common rate of the majority of states.
- Row 14, net earnings before interest after credit, control and tax, shows the effect of NSPS control costs and the investment tax credit on after tax earnings. It is derived by subtracting

federal tax liability after credit, the minimum tax and state tax, from Row 8. As can be seen, this figure varies over the years as control cost absorbed is lowered and as the original tax credit is exhausted and credit for new rolling stock is taken and exhausted and as interest payments are reduced. Net earnings before interest after credit, control and tax is the first category of our cash flow. All succeeding categories also affect cash flow.

- Row 15 is added to Row 14 and represents depreciation of stationary stock, depreciated straight line over 10 years.
- Row 16, depreciation of rolling stock, is added to the above. This depreciation, which is taken over 7 years, comes into play in later years as new rolling stock is purchased in years 1984 and 1991.
- Row 17, depreciation of control equipment, is taken over 10 years and added to the other depreciable equipment.
- Row 18, depletion, is added to the cash flow since all of these industries are in the mining classification and depletion allowance increases cash flow.

(Depletion can be taken in one of two ways: cost depletion or percentage depletion. Cost depletion is dependent on the cost basis of the land, amount of mineral mined and estimated amount of mineral reserves. Percentage depletion is based on a specified percentage of sales revenue, the percentage differs by industry, to a maximum of 50% of taxable income before depletion is counted. Cost depletion cannot be calculated here because it is site specific; i.e., dependent on the cost of the property and reserves on the property. In any case, most companies generally use percentage depletion. In the example depletion is shown as $2,000 in 1977. The percentage depletion allowance for stone is 5%. For 1977 this amounts to $17,600, but the plant can only use $2,000 because of the 50% taxable income limit.)

- Row 19, working capital recovery, shows that at the end of the project working capital is recovered. Working capital is taken to be 4% of revenue.
- Row 20, cash inflow, shows for each year the expected total of the above cash flow categories, and is the amount which must be discounted to the present by the discount factors shown in row 21. Row 22 is the result; i.e., Row 20 multiplied by Row 21.
- Row 23, cash outflow, shows the investment expenditures necessary to establish the operation. Investment of $1.1 million is made initially and subsequent rolling stock investment is made in years 1984 and 1991. These cash outflows are discounted by the appropriate discount factors of Row 21. Row 24 is the result.

The weighted average cost of capital of 11.8% generates the discount factor for each year of the 20 year period. These factors show the present value of a dollar of future cash flow for each future year. After the annual cash flows are discounted, they are summed to derive the present value of the cash inflows over the life of the project. This cash inflow is then compared to the cash outflow, which is the present value of the total investment. In this example the present value of net cash inflows is greater than the present value of cash outflows, so that an investment in a 136 Mg/hr (150 tph) crushed stone plant with NSPS controls attached is profitable at a weighted average cost of capital of 11.8%.

8.4.6 Findings

Table 8-40 presents the results of this analysis for each size plant of the potentially significantly affected industries. For the 9 and 23 Mg/hr (10 and 25 tph) sand and gravel, and crushed stone plants the DCF

Table 8-40

SUMMARY OF DCF RESULTS

Grassroots Plants
Investment Decision

Industry	Size - Mg/hr (tons per hour) 9 (10)	 23 (25)	 68 (75)	 136 (150)	 272 (300)	 544 (600)
Pumice	NF	F	F	N.A.	N.A.	N.A.
Sand & Gravel	NF[1]	NF[1]	A[1]	F	F	F
Crushed Stone	NF[1]	NF[1]	A[1]	F	F	F
Common Clay	NF	A	F	F	N.A.	N.A.
Gypsum	A	F	F	N.A	N.A.	N.A.
Perlite	F	F	F	N.A.	N.A.	N.A.

1. Equipment suppliers and industry representatives do not expect plants of this size to be constructed even in the absence of NSPS.

Key:
F - economically feasible to construct
NF - not economically feasible to construct
A - ambiguous
N.A. - Not Applicable because plants of this size are not likely to be constructed in the absence of NSPS.

analysis indicates that the investment is not economically feasible. The same result holds for the 9 Mg/hr (10 tph) common clay plant.

For the 68 Mg/hr (75 tph) sand and gravel, and crushed stone plants, the 23 Mg/hr (25 tph) common clay plant and the 9 Mg/hr (10 tph) gypsum plant, the DCF analysis showed negative discounted cash flows ranging from less than 2% of total investment for common clay to approximately 16% for gypsum. An internal rate of return (IRR) was calculated for each of these four model plants. The internal rate of return is that rate which makes the discounted cash outflow. The IRR varied from approximately 8.5% for gypsum to slightly less than 10% for common clay. Since the net discounted cash flows were only slightly negative; i.e., the IRR was fairly close to 11.8% cost of capital, small changes in the parameters of the worst case analysis would produce positive net discounted cash flows. For this reason the 68 Mg/hr (75 tph) sand and gravel, and crushed stone plants, the 23 Mg/hr (25 tph) common clay plant and the 9 Mg/hr (10 tph) gypsum plant are determined to be economically feasible to construct, if the conservative assumptions used throughout this report are relaxed.

Table 8-41 shows the results of the DCF analysis on expansions of 4.5 and 9 Mg/hr (5 and 10 tph) grinding capacity in the common clay and gypsum industries. In the analysis the expansion was assumed to take place in the smallest size existing plant; i.e., 9 Mg/hr (10 tph), in order to provide a "worst case" situation. The control costs were assumed to be spread over both new and existing output based on the ratio of new to existing output. As is shown in Table 8-41, all expansion size plants except the 4.5 Mg/hr (5 tph) common clay plant were determined to be economically feasible to construct.

Table 8-41

SUMMARY OF DCF RESULTS

Expansions
Investment Decison

INDUSTRY	Size Mg/hr (tph) 4.5 (5)	9 (10)
Common Clay	A	F
Gypsum	F	F

Key: F - economically feasible to construct

A - ambiguous

It should be kept in mind that because an investment is found to be economically feasible from a DCF analysis it does not necessarily mean that the investment will, in fact, be made by a company.

NSPS control costs will not significantly affect those non-metallic mineral industries for which a DCF analysis was not performed. As seen in Table 8-36 the greatest potential NSPS control cost absorption is less than or equal to 2% of product price, since these non-metallic minerals all have a higher product price than those non-metallic minerals for which a DCF analysis was performed. The process economics are similar for both industries for which a DCF analysis was performed and for which a DCF analysis was not performed. Since the DCF analysis was favorable for industries whose potential control cost absorption was equal to or greater than 4% of product price, the DCF analysis will be favorable for industries where this ratio was equal to or less than 2%. For this reason a DCF analysis performed on each of those 17 non-metallic minerals excluded from further consideration in Table 8-36 would show an economically feasible investment decision for all size new plants.

Crushing and grinding facilities are also a portion of production operations whose final output is not a specific type of non-metallic mineral, such as at lime and power plants; i.e, crushing and grinding are intermediate processes in these industries.

These intermediate processing facilities are usually constructed by firms in the above mentioned industries because the need for the non-metallic mineral is large enough to support such a facility. Such intermediate facilities can produce the requisite size mineral at a lower cost to the firm than can be attained from buying the mineral from an independent producer. Consequently, some cost increase could be sustained by intermediate processing facilities and still permit them to be competitive with firms that purchase the requisite size material from independent producers. Furthermore, the intermediate processor is able to spread the incremental cost over a final product whose selling price is larger than that of the non-metallic mineral input, and, thus can more readily pass on these costs. Finally, because of their affiliation with larger companies, these facilities would tend to have a lower cost of capital. Therefore, the investment decision resulting from the DCF analysis for various plant sizes in the non-metallic mineral industries per se would likely hold for intermediate processing facilities (that are part of other facilities).

8.5 POTENTIAL SOCIO-ECONOMIC AND INFLATIONARY IMPACTS

8.5.1 Industry Cost Totals

Table 8-42 presents the upper limit to the number of typical new plants which will be constructed in each industry in each of 5 years based on projected industry growth and the typical plant size in each industry. The projections of new plants required is based on growth from 1975 production statistics and assumes that 1975 production equals capacity. To the extent that actual production was lower than capacity production, the number of estimated typical size plants required each year will be lower. Therefore required total industry annualized control costs will be lower.

Table 8-43 indicates the cumulative annualized industry capital and operating costs in 1976 dollars to meet the NSPS standard. The totals are derived by multiplying the estimated number of typical plants to be constructed in each year by the annualized control costs for these size plants. As can be seen, the crushed stone industry would have the largest annualized costs by the fifth year, $19.2 million.

Table 8-44 shows the average annualized cost per ton of output in the fifth year after control. These figures are based on the estimated cumulative annualized costs in the fifth year, Table 8-43, divided by the estimated total industry production in the fifth year. Kyanite shows the largest industry cost per ton of $0.137 per ton. Table 8-44 also shows that control cost per ton as a percent of price per ton is highest for pumice, 1.7%.

New regulations shall be considered a major action if "additional annualized cost of compliance, including capital charges (interest and depreciation), will total $100 million (i) within any one of the first 5 years of implementation, or (ii) if applicable, within any calendar year up to the date by which the law requires attainment of the relevant pollution standard," or "total additional cost of production of any major industry product or service will exceed 5 percent of the selling price of the product." Total industry annualized control cost in the fifth year after promulgation of NSPS and control cost as a percent of selling price are lower than the guidelines set for these measures of $100 million for annualized capital and operating expense and 5 percent, respectively.

TABLE 8-42 ESTIMATED NUMBER OF TYPICAL NEW PLANTS REQUIRED TO MEET PROJECTED PRODUCTION*

Industry	Typical size (Mg/hr)	Growth rate (%)	1980	1981	1982	1983	1984
Pumice	9	3.5	2	2	2	2	2
Sand and Gravel	272	1.0	14	14	14	14	15
Crushed Stone	272	4.0	72	75	78	81	85
Common Clay	23	3.5	10	10	10	11	11
Gypsum	23	2.0	1	1	1	1	1
Perlite	23	4.0	-	1	1	-	1
Rock Salt	68	2.0	2	2	3	3	3
Sodium Compounds	23	2.5	-	1	1	1	-
Talc	9	4.0	-	1	1	-	1
Barite	9	2.2	-	-	1	-	-
Boron	272	5.0	-	-	-	-	-
Fluorspar	9	3.0	-	-	-	-	1
Feldspar	9	4.0	-	-	1	-	-
Diatomite	23	5.5	-	-	1	-	-
Vermiculite	68	4.0	-	-	-	-	1
Mica	9	4.0	-	-	-	-	1
Kyanite	9	6.0	-	-	-	-	1
Gilsonite	9	-	-	-	-	-	-

*Whenever the projected production for a given year was not enough to justify the building of a new typical size plant, no new plants were assumed to be built.

TABLE 8-43 ANNUALIZED CAPITAL AND OPERATING CONTROL COSTS FOR NEW PLANT CONSTRUCTION

Industry	Annualized cost (in thousands of dollars)				
	1980	1981	1982	1983	1984
Pumice	42.4	84.8	127.2	169.6	212.0
Sand and gravel	777	1,554	2,331	3,108	3,940.5
Crushed stone	3,996	8,158.5	12,487.5	16,983	21,700.5
Common clay	234	468	702	959.4	1,216.8
Gypsum	23.4	46.8	70.2	93.6	117
Perlite	-	16	32	32	48
Rock salt	46.8	93.6	163.8	234	304.2
Sodium compounds	-	23.4	46.8	70.2	70.2
Talc	-	21.2	424	42.4	63.6
Barite	-	-	21.2	21.2	21.2
Boron	-	-	-	-	-
Fluorspar	-	-	-	-	21.2
Feldspar	-	-	21.2	21.2	21.2
Diatomite	-	-	23.4	23.4	23.4
Vermiculite	-	-	-	-	23.4
Mica	-	-	-	-	21.2
Kyanite	-	-	-	-	21.2
Gilsonite	-	-	-	-	-
Total					27,825.6

TABLE 8-44 ANNUALIZED CONTROL COST PER TON OF INDUSTRY OUTPUT IN 5TH YEAR AND CONTROL COST AS PERCENT OF SELLING PRICE

Industry	Control cost per ton ($)	Annualized cost/ton ÷ price/ton
Pumice	0.043	1.7 %
Sand and gravel	0.005	0.2
Crushed stone	0.018	0.8
Common clay	0.019	0.9
Gypsum	0.01	0.2
Perlite	0.051	0.3
Rock salt	0.017	0.1
Sodium compounds	0.012	0.03
Talc	0.049	0.1
Barite	0.014	0.1
Boron	-	-
Fluorspar	0.123	0.1
Feldspar	0.023	0.1
Diatomite	0.026	0.03
Vermiculite	0.052	0.1
Mica	0.116	0.3
Kyanite	0.137	0.2
Gilsonite	-	-

*Based on 1976 average F.O.B. mine selling price and 1978 production figures.

APPENDIX A

EVOLUTION OF THE BACKGROUND INFORMATION DOCUMENT

TABLE A-1. EVOLUTION OF THE BACKGROUND INFORMATION DOCUMENT

Date	Company, consultant or agency	Location	Nature of action
04/30/73	Arizona Portland Cement Ideal Cement Albuquerque Gravel Products	Rillito, Ariz. Tijeras, N. Mex. Albuquerque, N. Mex.	Presurvey two sources. Inspect haul road fugitive dust control technique.
09/13/73	Harry T. Campbell and Sons Texas Plants	Texas, Md.	Measure visible emissions from the asphalt batch plant.
10/13/73	Nello L. Teer Company	Raleigh, N.C.	Inspect stone processing and quarrying operations.
01/16/74	Paul Lime Plant, Inc. Arizona Portland Cement Co.	Douglas, Ariz. Rillito, Ariz.	Presurvey two quarries and stone processing plants for particulate testing.
02/13/74	Ideal Cement Co. Albuquerque Gravel Products, Inc. H.G. Fenton Material Co.	Tijeras, N. Mex. Albuquerque, N. Mex. San Diego, Calif.	Inspect crushed stone plants
05/28/74	Essex Bituminous Concrete Corp.	Dracut, Mass.	Presurveys of five crushed stone plants for testing
to			
05/31/74	Essex Bituminous Concrete Corp. Blue Rock Industries Lynn Sand and Stone Co. Massachusetts Broken Stone Co.	Peabody, Mass. Westbrook, Maine Swampscott, Mass. Weston, Mass.	
05/14/74	Kentucky Stone Co.	Russellville, Ky.	Presurveys of two crushed stone plants for testing.
to			
05/15/74	Caldwell Stone Co.	Danville, Ky.	
06/03/74	Arizona Portland Cement Company	Rillito, Ariz.	Conduct emission tests for particulate emission
06/02/74	Arizona Portland Cement Company	Rillito, Ariz.	Test report for particulate emission testing.
08/06/74 to 08/08/74	General Crushed Stone Co. Pennsy Supply Inc. J. M. Brenner Stone Co.	Quakertown, Pa. Harrisburg, Pa. Lancaster, Pa.	Presurveys for particulate emission tests.
09/16/74	Essex Bituminous Concrete Co.	Dracut, Mass.	Trip report of emission tests on stone crushing operations.
10/28/74	Kentucky Stone Co.	Russellville, Ky.	Tests conducted for process and fugitive [illegible]ions.
11/19/74	J. M. Brenner Co.	Lancaster	[illegible] test of two baghouse operations [illegible]ushed stone plant.
12/27/74	Essex Bituminous Concrete Co.		Source testing report of stone crushing operation.

(continued)

TABLE A-1 (continued)

Date	Company, consultant or agency	Location	Nature of action
12/20/74	Ferrante and Sons	Bernardsville, N.J.	Emission test report of stone crushing operation.
06/30/75	Kentucky Stone Co.	Russellville, Ky.	Source tests on primary, secondary crushers, three deck screens, and crusher feed hopper.
07/08/75	Arizona Portland Cement	Rillito, Ariz.	Trip report of visible emissions observations at stone crushing facility.
11/13/75	Massachusetts Broken Stone Co.	Weston, Mass.	Report on observation of visible emission at stone processing operation.
04/13/76	Blue Ridge Stone Corp.	Martinsville, Va.	Plant visit to study process operation at crushed stone plant.
05/06/76	Potash Company of America	Carlsbad, N. Mex.	Plant visit to study processing of potash ore.
05/27/76	Dravco Corp.	Newtown, Ohio	Plant visit to study processing of sand and gravel and the resultant particulate emissions.
05/12/76	GREFCo, Inc.	Socorro, N. Mex.	Plant visit to study processing of perlite ore and the resultant particulate emissions.
05/11/76	U.S. Borax	Boron, Calif.	Plant visit to study processing of borate ore and resultant particulate emissions.
05/27/76	Dravco Corp.	Newtown, Ohio	Plant visit made by PEDCo Environmental Specialists, Inc.
06/10/76	Flintkote Co.	Las Vegas, Nev.	Plant visit made by PEDCo and EPA to study gypsum processing operations.
06/24/76	Englehard Minerals and Chemicals Co.	Attapulgus, Ga.	Plant visit to observe fuller's earth processing and resultant particulate emissions.
06/23/76	Georgia Kaolin Co.	Dry Branch, Ga.	Plant visit to observe kaolin processing operations and resultant particulate emissions.
07/08/76	Standard Slag Co.	Warren, Ohio	Plant visit to observe slag processing and resultant particulate emissions.
07/09/76	Ozark-Mahoning Co.	Rosiclare, Ill.	Plant visit to observe fluorspar processing and resultant particulate emissions.
07/07/76	International Salt Co.	Retsof, N.Y.	Plant visit to observe rock salt processing and resultant particulate emissions.
07/06/76	Eastern Magnesia Talc Co.	Johnson, Vt.	Plant visit to observe talc processing and resultant particulate emissions.
08/26/76	Massachusetts Broken Stone	Weston, Mass.	Visible emissions tests conducted at stone processing operations.
09/27/76	International Minerals and Chemicals Corp.	Spruce Pine, N.C.	Source sampling at feldspar milling operation for particulates.

(continued)

TABLE A-1 (continued)

Date	Company, consultant or agency	Location	Nature of action
10/25/76	Flintkote Co.	Blue Diamond, Nev.	Stationary source testing of gypsum milling operation.
10/21/76	Eastern Magnesia Talc Co.	Johnson, Vt.	Stationary source testing at several milling operations at talc processing plant.
11/10/76			Source sample analysis for physical characteristics of particulate samples from several plants.
05/09/77	Pfeizer Inc.	Victorville, Calif.	Presurvey talc grinding operations for possible source testing.
05/10/77	Johns-Manville Corp.	Lompoc, Calif.	Presurvey diatomite processing operations for possible source testing.
06/20/77	Pfeizer, Inc.	Victorville, Calif.	Source test on pebble mill at talc processing plant.
06/20/77	Pfeizer, Inc.	Victorville, Calif.	Source emission test report performed by Pacific Environmental Services, Inc.
07/11/78	National Air Pollution - Control Techniques and Advisory Committee (NAPCTAC)	Raleigh, N.C.	Meeting with non-metallic industry spokesmen to discuss proposed NSPS.
08/16/78	National Asphalt Pavement Association	Durham, N.C.	Meeting with National Asphalt Pavement Association to discuss proposed NSPS.
08/29/78	Kaolin Industry	Durham, N.C.	Meeting between EPA and the Kaolin Industry to discuss the proposed NSPS as it pertains to the Kaolin Industry.
09/14/78	National Slag Association	Durham, N.C.	Meeting between EPA and the association to discuss the proposed NSPS as it pertains to the slag industry.
10/03/78	National Limestone Institute	Washington, D.C.	Meeting between Institute and EPA to discuss proposed NSPS as it pertains to the limestone industry.
12/05/78	Georgia Kaolin Company	Dry Branch, Ga.	Source test report on Raymond Impact Mill and Roller Mill.
12/06/78	Thiele Kaolin Company	Sandersville, Ga.	Fugitive emission testing at product loading facility at kaolin plant.
12/20/78	Edward C. Levy Co.	Detroit, Mi.	Plant visit by GCA/Technology Division to observe slag processing and resultant particulate emission. Source testing performed by Clayton Associates same date.
01/09/79	Colorado Sand and Gravel Association	Durham, N.C.	Meeting with EPA to discuss proposed NSPS.
01/10/79	North State Pyrophyllite Company	Greensboro, N.C.	Meeting with GCA/Technology Division to discuss problems plant would have with proposed NSPS.
01/22/79	Gypsum Association	Durham, N.C.	Meeting between the Association and EPA to discuss the proposed NSPS as it pertains to the gypsum industry.
02/21/79 to 02/23/79	Colorado Sand and Gravel Association	Denver, Col.	GCA/Technology Division visited several sand and gravel processing plants and met with the Association to discuss the proposed NSPS as well as to observe process and emission control techniques used at the sand and gravel plants.

(continued)

TABLE A-1 (continued)

Date	Company, consultant, or agency	Location	Nature of action
03/06/79	Refractories Institute	Durham, N.C.	Meeting between Institute and EPA to discuss the proposed NSPS as it pertains to the Refractories Industry.
04/03/79	P-Stone, Incorporated	Opal, Pa.	Plant visit by GCA/Technology Division to investigate portable plant using baghouse to control dust emitted by process.
04/19/79	Iowa Manufacturing Co.	Durham, N.C.	Meeting between company and EPA to discuss the proposed NSPS as it pertains to the crushed stone industry.
08/15/79	Johnson-March Company	Philadelphia, Pa.	Meeting with GCA/Technology Division to gather information on wet dust suppression control systems.
08/24/79 to 08/31/79	Tillcon-Tomasso, Inc. Castle Concrete Co. Schmidt-Tiago Construction Co. Cooley Gravel Co. Brannan Sand and Gravel Co. Mobile Pre-Mix Co. Gifford-Hill & Co. Lone Start Industries	N. Branford, Conn. Colorado Springs, Colo. Eagle, Colo. Morrison, Colo. Denver, Colo. Golden, Colo. Chico, Tex. Bridgeport, Tex.	Presurvey ten stone crushing and sand and gravel plants by GCA/Technology Division for visible emission testing. (Plants controlled by wet suppression.)
09/06/79 to 09/17/79	Vulcan Materials Co. Vulcan Materials Co. Martin-Marietta Co. Martin-Marietta Co. Nello L. Teer Co. Luck Quarries Vulcan Materials Co. Flintkote Stone Products Co. Martin-Marietta Co. Vulcan Materials Co.	Helena, Ala. Newman, Ga. Augusta, Ga. Columbia, S.C. Rocky Mount, N.C. Manakin, Va. Stafford, Va. Frederick, Md. Jamestown, N.C. Stoneville, N.C.	Presurvey ten stone crushing and sand and gravel plants by GCA/Technology Division for visible emission testing. (Plants controlled by wet suppression.)
10/02/79 to 10/30/79	Vulcan Materials Co. Castle Concrete Co. Brannan Sand & Gravel Co. Vulcan Materials Co. Flintkote Stone Products Co.	Helena, Ala. Colorado Springs, Colo. Denver, Colo. Stafford, Va. Frederick, Md.	Visible emission testing at several crushers, screens, transfer points, etc. controlled by wet suppression at five crushed stone and sand and gravel plants.
10/15/79	Southern California Rock Products Association	Durham, N.C.	Meeting between association and EPA to discuss ambient monitoring data performed by the association.
11/20/79	Georgia Kaolin, Industry	Durham, N.C.	Meeting between industry representatives and EPA to discuss the proposed NSPS as it pertains to the Kaolin Industry.
01/15/80	National Crushed Stone Association, National Sand & Gravel Association	Durham, N.C.	Meeting between associations and EPA to discuss recent visible emission tests performed by EPA and ambient monitoring data performed by the association.
10/27/82	National Crushed Stone Association, National Sand & Gravel Association	Washington, D.C.	Meeting between associations and EPA to discuss the designation of affected facilities.

APPENDIX B

INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS

This appendix consists of a reference system, cross-indexed with the October 21, 1974 FEDERAL REGISTER (39 FR 37419) containing the Agency guidelines concerning the preparation of Environmental Impact Statements. This index can be used to identify sections of the document which contain data and information germane to any portion of the FEDERAL REGISTER guidelines.

APPENDIX B

Cross-Indexed Reference System to Highlight Environmental Impact Portions of the Document

Agency Guidelines for Preparing Regulatory Action Environmental Impact Statements (39 FR 37419)	Location Within the Background Information Document
(1) Background and summary of regulatory alternatives	The regulatory alternatives from which standards will be chosen for proposal are summarized in Chapter 1, section 1.1, pages 1-1 through 1-4.
Statutory basis for proposing standards	The statutory basis for proposing standards is summarized in Chapter 2, section 2.1, pages 2-1 through 2-6.
Relationship to other regulatory agency actions	The various relationships between the regulatory agency actions are discussed in Chapters 3, 7, and 8.
Industry affected by the regulatory alternatives	A discussion of the industries affected by the regulatory alternatives is presented in Chapter 3, section 3.1, pages 3-1 through 3-12. Further details covering the "business/economic" nature of the industries is presented in Chapter 8, secion 8.1, pages 8-1 through 8-51.
Specific processes affected by the regulatory alternatives	The specific processes and facilities affected by the regulatory alternatives are summmarized in Chapter 1, section 1.1, pages 1-1 through 1-4. A detailed technical discussion of the sources and processes affected by the regulatory alternatives is presented in Chapter 3, section 3.2, pages 3-12 through 3-51.

APPENDIX C

SUMMARY OF TEST DATA

A test program was undertaken by EPA to evaluate the best particulate control techniques available for controlling particulate emissions from non-metallic mineral plant process operations including crushers, screens and material handling operations, especially conveyor transfer points. In addition, a control technique for grinding operations was also evaluated. This appendix describes the process operations tested (their operating conditions, characteristics of exhaust gas streams and, where applicable, deviations from prescribed test procedures) and summarizes the results of the particulate emission tests and visible emission observations.

Sixteen baghouse collectors controlling process operations at five crushed stone installations (three limestone and two traprock), one kaolin, and one fuller's earth plant were tested using EPA Reference Method 5 except as noted in the facility descriptions for determination of particulate matter from stationary sources. Baghouse collectors utilized to control particulate emissions from grinding operations at a feldspar, gypsum, and two talc plants were also tested, but EPA Reference Method 17 was used for determination of particulate matter. Results of the front-half catches (probe and filter) from the particulate emission measurements conducted are shown in Figure C-1 and the complete results are summarized in the Tables herein.

Visible emission observations were made at the exhaust of each of the above control devices in accordance with procedures recommended in EPA

Reference Method 9 for visual determination of the opacity of emissions from stationary sources.

At the hoods and collection points for the process facilities, the visible emission opacity observations were made in accordance with procedures recommended in EPA Reference Methods 9 and 22 and the data are presented in terms of percent of time equal to or greater than a given opacity or in percent of total time of visible emissions as in Table 102. Visible emission observations were also made at four crushed stone, two sand and gravel plants and a feldspar crushing plant where particulate emissions are controlled by dust suppression techniques. The results of these tests are given in Table 102 (Method 22 data) and Figures 2 through 6 (Method 9 data).

DESCRIPTION OF FACILITIES

A1. Primary crushing stage incorporating a pan feeder, vibrating grizzly, impact breaker, T-bar belt feeder and a primary belt conveyor. The impactor is rated at 1,000 TPH and used to reduce run-of-quarry limestone (cement rock) to 2 1/2-inch minus. Particulate emissions generated at various points are confined, captured and vented to a jet pulse type baghouse for collection. Tests were conducted only during periods when the process was operating normally. Particulate measurements were performed using EPA Method 5. Visible emission observations were made at the baghouse exhaust and at capture points in accordance with EPA Method 9.

A2. Primary scalping screen used for scalping the primary crusher product of facility A1. The plus 2 1/2-inch oversize is chuted to a belt conveyor and returned to the primary for recrushing. The screen throughs are also discharged to a conveyor and transported to a storage facility. Particulate emissions generated from the top of the screen, which is totally enclosed, and from both chute-to-belt transfer points are aspirated to a jet pulse baghouse for collection. Tests, using EPA Method 5, were conducted simultaneously with those at facility A1. Sampling during all three tests runs reported herein was overisokinetic. Visible emission observations were made at the baghouse exhaust using EPA Method 9.

A3. Conveyor transfer point at the tail of an overland conveyor, also located at installation A1. The 30-inch belt conveyor has a 900 TPH capacity at a belt speed of 700 FPM. The transfer point is enclosed and emissions vented to a small baghouse unit for collection. Three particulate samples were collected using EPA Method 5. Visible emission observations were made at the baghouse outlet and at the transfer point using EPA Method 9.

A4. The secondary crushing and screening stage at installation A1. consisting of a vibrating screen and a cone crusher. Minus 2 1/2-inch material is fed to the screen at about 165 TPH where it is separated in two fractions, plus 3/4-inch and 3/4-inch minus. The oversize fraction is discharged to the cone crusher and reduced to 3/4-inch. The crusher product and screen throughs are then conveyed to a milling circuit. Dust control is effected by capturing and venting emissions from the screen and crusher to a jet pulse baghouse for collection. Both particulate measurements and visible emission observations were made at the collector outlet using EPA Methods 5 and 9, respectively.

B1. Primary impact crusher used for the initial reduction of run-of-quarry limestone rock to three inches. The normal production rate through this primary crushing stage is 350 TPH. Particulate emissions are collected from the impact crusher at its discharge hopper and from the discharge hopper to primary conveyor belt transfer point and then controlled by a fabric filter collector. The fabric filter is mechanically shaken twice daily for cleaning. EPA Method 5 was used for particulate measurements and EPA Method 9 was used for visible emission readings at the collector exhaust and at the impact crusher.

B2. Secondary and tertiary crushing and screening facilities at the same installation as B1. These consist of a scalping screen, a 4-foot cone crusher, two 3-foot cone crushers, a hammermill used to produce agstone and two final sizing screens. The plant has a 300 TPH design capacity, crushing to 1 1/2-inch minus, including 60 TPH of agstone. Dust control throughout this plant is affected by enclosing or hooding dust producing points and venting captured emissions to a fabric filter for collection. The collector is mechanically shaken twice daily for cleaning. Pickup points include the top of the scalping screen, both the feed and discharge of all three cone crushers, the discharge of the hammermill, the top of both finishing screens, five product bins and six conveyor transfer points. Three particulate measurements were made in accordance with EPA Method 5. In addition, visible emission observations were made at the baghouse exhaust and at the process facilities controlled using EPA Method 9.

B3. The same facility as B2, except that particulate emission measurements were made using an in-stack filter. Testing was conducted simultaneously with that described in B2.

C1. Limestone crushing plant consisting of a primary jaw crusher, scalping screen and hammermill. The rated capacity of the plant is 125 TPH. End products produced range from 1 1/2-inch minus dense-graded road base stone to minus 1/8-inch screenings. Particulate emissions are controlled by a mechanical shaker type baghouse. Collection points include the primary crusher discharge, the scalping screen throughs to stacking conveyor transfer point, and both the hammermill feed and discharge. Tests were conducted using EPA Methods 5 and 9.

C2. Two 3-deck vibrating screens used for final sizing at the same installation as C1. Both screens are totally enclosed and particulate emissions collected from the top of both screens, at the feed to both screens, and at both the head and tail of a shuttle conveyor between the screens are vented to a mechanical shaker type baghouse. Again, tests were conducted in accordance with EPA Methods 5 and 9.

D1. Secondary and tertiary crushing and screening facilities used for processing traprock at 250 TPH. The process facilities include a scalping screen, a 4-foot secondary cone crusher, two sizing screens and two 4-foot tertiary cone crushers. All process facilities are enclosed and particulate emissions are vented to one of two baghouses for collection. The baghouses are exhausted through a common stack. Particulate measurements were conducted using EPA Method 5. Visible emission observations using EPA Method 9 were also made at the collector exhaust and at the process facilities controlled.

D2. Finishing screen at the same installation as facility D1. The screen is totally enclosed and emissions collected from the top of the screen enclosure, all screen discharge points, and several conveyor transfer points are vented to a fabric filter. Tests conducted were identical to those at D1 and were performed simultaneously.

E1. Tertiary crushing and screening facilities at a 375 TPH traprock installation. Process facilities include two sizing screens, four 4 1/4-foot cone crushers and several conveyor transfer points. Both screens are enclosed and emissions are collected by the enclosures and at the throughs discharge. The tertiary cone crushers are hooded and vented at both feed and discharge points. Captured emissions are collected by a jet pulse type baghouse. Tests using EPA Method 5 were conducted during periods of normal operation. Although desirable, the pressure drop across the baghouse could not be monitored because the pressure gauge was inoperative. Visible emission observations were also made of the baghouse exhaust using EPA Method 9.

E2. Five screens used for final sizing and eight storage bins at the same installation as E1. All screens and bins are totally enclosed and emissions vented to a jet pulse type baghouse for collection. Tests conducted were identical to and performed simultaneously with those at facility E1.

F1. Tertiary crushing and screening facilities used to reduce run-of-quarry trap rock. Particulate emissions are controlled by spraying water at critical dust producing points in the process flow. Two to three percent moisture is added to the material to suppress dust. Visible emission observations were made in accordance with EPA Method 9 procedures.

G1. Grinding system incorporating a belt feeder, ball mill, bucket elevator, separator and a belt conveyor. The ball mill is used to reduce feldspar to minus 200 mesh. Particulate emissions generated at various points are confined, captured and vented to a reverse air type baghouse for collection. Particulate measurements were performed using EPA Method 17. Visible emission observations were made at the baghouse exhaust and all capture points in accordance with EPA Method 9.

G2. Crushing facilities (primary and secondary) used to reduce feldspar to minus 1.5 inches. Dust control is affected by the suppression techniques. Surface moisture contents were 1.6 to 1.8 percent at the primary crusher discharge, 1.4 to 1.5 percent at the secondary crusher feed, and 1.0 percent at the secondary crusher discharge conveyor. Visible emission observations were made at all process facilities in accordance with EPA Method 9 procedures.

H1. Raymond roller mill used to grind gypsum. The ground product from the mill is air-conveyed to a cyclone collector for product recovery. The air is returned to the mill. Excess air is vented to a baghouse. Visible emission observations were made to determine leaks from the system in accordance with EPA Method 9 procedures.

H2. Same facility as H1. Particulate measurements and visible emission observations were made at the baghouse exhaust in accordance with EPA Methods 5 and 9.

I. Bagging operation used to package ground mica. Particulate emissions are controlled by a baghouse. Visible emission observations were made at the capture point in accordance with EPA Method 9 procedures.

J1. Crushing (primary and secondary), grinding (pebble mill and vertical mill) and bagging operations at a talc processing plant. Particulate emissons are controlled by a baghouse. Visible emission observations were made at the capture points in accordance with EPA Method 9 procedures.

J2. Same facility as J1. Particulate measurements and visible emission observations were made at the baghouse exhaust in accordance with EPA Methods 5 and 9.

K. Pebble mill used to grind talc. Captured emissions are vented to a pulse type baghouse for collection. Particulate measurements and visible emission observations were made at the baghouse exhaust in accordance with EPA Methods 5 and 9.

L1. Raymond Impact Mill used to grind kaolin. Captured emissions are exhausted to a baghouse for collection. EPA Methods 5 and 9 were used for particulate measurement and visible emission observation at the baghouse stack, respectively.

L2. Roller Mill used at same plant as L1. Further grinding of kaolin is accomplished. Collection of captured emissions takes place in a baghouse which was tested for the same parameters as L1, again by EPA Methods 5 and 9.

M1. Roller mill used to grind fuller's earth clay. Captured emissions are exhausted to a baghouse for collection. Particulate measurements and visible emission observations were made at the baghouse exhaust in accordance with EPA Methods 17 and 9.

M2. Fluid energy mill used to grind fuller's earth clay at same plant as M1. Captured emissions are exhausted to a baghouse for collection. EPA Methods 17 and 9 were used for particulate measurement and visible emission observation at the baghouse stack, respectively.

N. Kaolin rail car loading operation. Three complete rail car loadings were evaluated for fugitive emissions in accordance with EPA Method 22 test procedures. A baghouse (collection system) is used to collect dust that is captured in the loading area.

P. Facility P produces crushed stone used primarily for road construction purposes. The processing operation is located in the bottom of an open quarry. The quarried materials are carried by truck to the upper rim of the pit where they are dumped into hoppers which feed the processing equipment. The finished product is transported back out of the quarry by belt conveyor.

Visible emission measurements were conducted at the primary (jaw), secondary (impact), and tertiary (cone) crushers, two process screens, and one conveyor transfer point by means of EPA Reference Methods 9 and 22. All process sources of emissions are directly or indirectly controlled by means of a wet suppression system.

Q. This facility produces two grades of rock for road-base and decorative stone, respectively. The ore is obtained from an open mining operation at the top of a mountain, and the process equipment is permanently installed in a descending arrangement from the mine site to the bottom of the mountain. The processed rock is accumulated in bins at the lower level for subsequent truck loading.

Visible emission measurements using the same techniques as Facility P were conducted at the primary (jaw), and secondary (cone) crushers, three process screens, and one conveyor transfer point all controlled by means of a wet suppression system.

R. A fully portable crushing plant processes bank-run material for road construction and as concrete component. Ore is removed from a gravel bank and trucked to the bank top for dumping into the initial screens before the primary crushers. Wet suppression techniques are used to control fugitive dust emanating from the processing of the material.

EPA Reference Methods 9 and 22 were used to measure visible emissions from primary (jaw), and secondary (cone) crushers, three process screens, and two conveyor transfer points.

S. The facility produces two grades of crushed limestone. The plant is relatively new with all process equipment located at ground level. One jaw crusher, two cone crushers, two process screens and two conveyor transfer points are all directly or indirectly controlled by means of wet suppression systems.

EPA Reference Methods 9 and 22 were employed to measure visible emissions emanating from the above named process sources.

T. A large semi-portable rock crushing facility processing large-size grades of crushed limestone was tested for visible emissions by means of EPA Reference Methods 9 and 22.

The sources tested were the primary and secondary (cone) crushers, one process screen, one conveyor transfer point, and one storage bin. All sources tested are controlled by the same techniques as Facilities P, Q, R, and S.

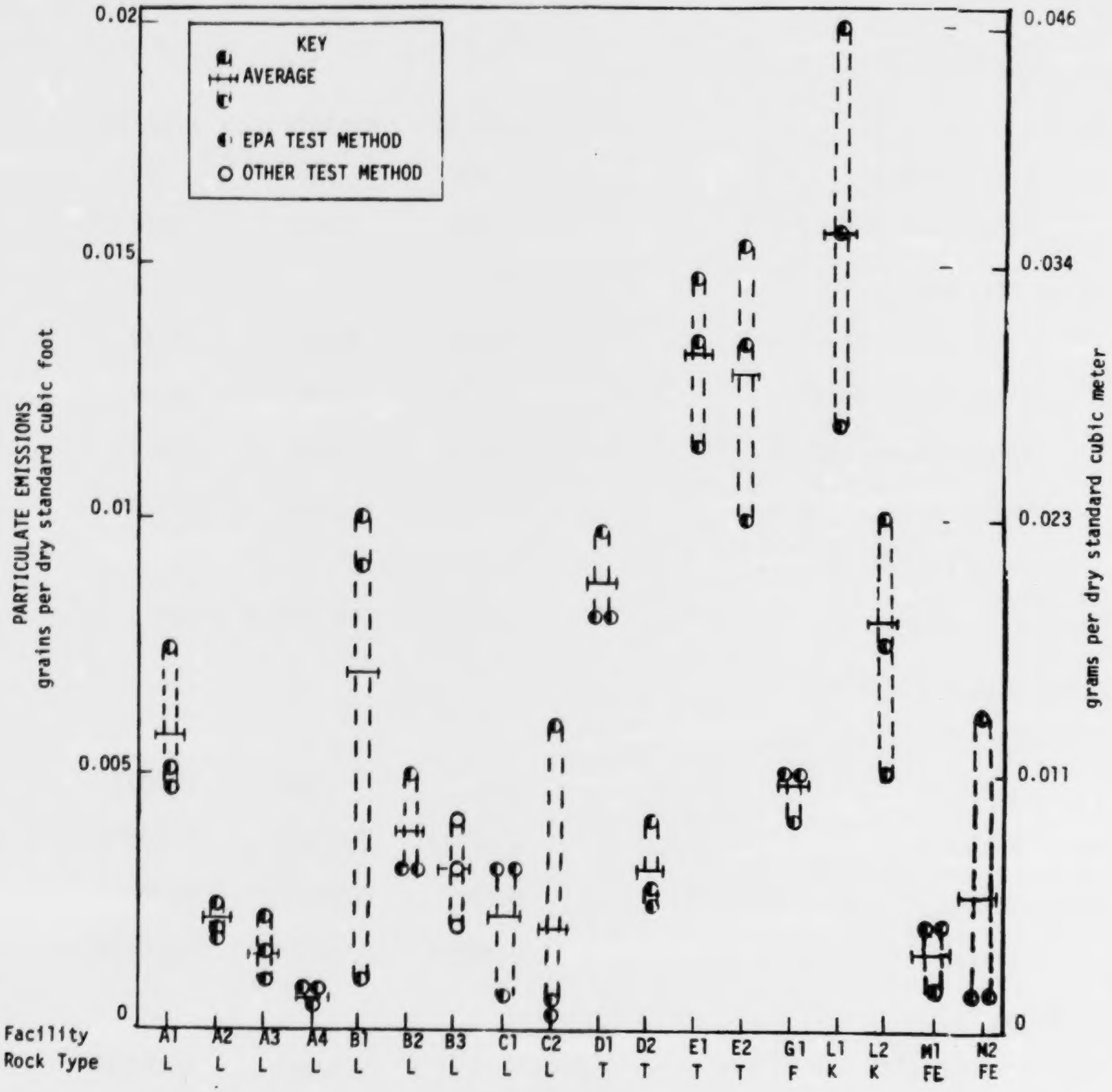


Figure C-1. Particulate emissions fron non-metallic minerals processing operations.

Reproduced from best available copy.

Table 1
FACILITY A1

Summary of Results

Run Number	1	2	3	Average
Date	6/10/74	6/11/74	6/12/74	-
Test Time-minutes	400	320	240	320
Production rate - TPH (1)	995	1027	1010	1011
Stack Effluent				
Flow rate - ACFM	26430	26653	27142	26472
Flow rate - DSCFM	22351	22140	22502	22331
Temperature - °F	81.0	88.0	88.0	85.7
Water vapor - Vol.%	2.5	3.0	3.3	2.9
Visible Emissions at Collector Discharge - Percent Opacity		See Tables 2 and 3		
Particulate Emissions				
Probe and Filter Catch				
gr/DSCF	0.00471	0.00504	0.00727	0.00567
gr/ACF	0.00398	0.00419	0.00602	0.00473
lb/hr	0.90	0.96	1.40	1.07
lb/ton	0.00091	0.00102	0.00139	0.00111
Total Catch				
gr/DSCF (2)	-	0.00597	0.00839	0.00718
gr/ACF	-	0.00495	0.00695	0.00595
lb/hr	-	1.13	1.62	1.38
lb/ton	-	0.00121	0.00160	0.00140

(1) Based on throughput through primary crusher.
(2) Back-half sample for run number 1 was lost.

TABLE 2

FACILITY A1

Summary of Visible Emissions(1)

Date: 6/4/74 - 6/5/74

Type of Plant: Crushed Stone - Primary Crusher

Type of Discharge: Stack

Distance from Observer to Discharge Point: 75 ft.

Location of Discharge: Baghouse

Height of Observation Point: Ground-level

Height of Point of Discharge: 14 ft.

Direction of Observer from Discharge Point: N.E.

Description of Background: Grey building

Description of Sky: Clear

Wind Direction: East

Wind Velocity: 0 - 5 mi/hr.

Color of Plume: None

Detached Plume: No

Duration of Observation: 6/4/74 - 78 minutes
6/5/74 - 210 minutes

SUMMARY OF AVERAGE OPACITY(1)

Set Number	Time		Opacity	
	Start	End	Sum	Average
1 through 6	8:50	9:26	0	0
7 through 9	11:23	11:41	0	0
10 through 13	12:12	12:36	0	0
14 through 48	8:11	11:41	0	0

Readings were 0 percent opacity during all periods of observation.

(1) Two observers made simultaneous readings.

TABLE 3

FACILITY A1

SUMMARY OF VISIBLE EMISSIONS[1]

Date: 7/8/75 - 7/9/75

Type of Plant: Crushed stone (cement rock)

Type of Discharge: Fugitive

Location of Discharge: Primary impact crusher discharge

Height of Point of Discharge: 6 feet

Distance from Observer to Discharge Point: 15 feet

Description of Background: Grey wall

Height of Observation Point: Ground level

Description of Sky: N.A. (indoors)

Direction of Observer from Discharge Point: SE

Wind Direction: N.A.

Wind Velocity: No wind (indoors)

Color of Plume: White

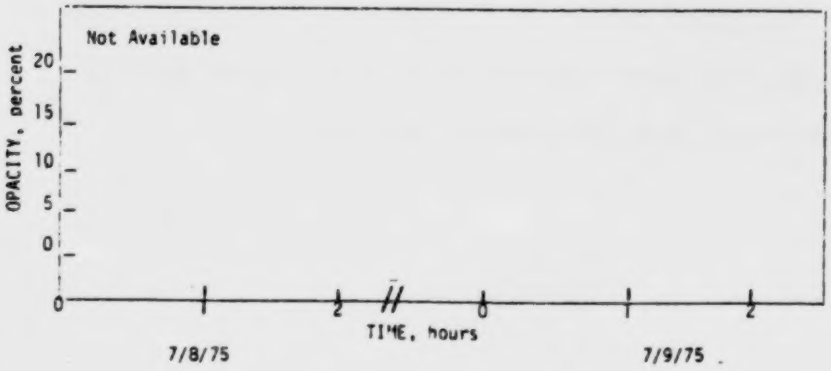
Detached Plume: No

Duration of Observation: 7/8/75 - 2 hours
7/9/75 - 2 hours

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity Min.	Sec.	Opacity, Percent	Total Time Equal to or Greater Than Given Opacity Min.	Sec.
5	3	30	55	-	-
10	0	30	60	-	-
15	0	15	65	-	-
20	0	15	70	-	-
25	0	0	75	-	-
30	-	-	80	-	-
35	-	-	85	-	-
40	-	-	90	-	-
45	-	-	95	-	-
50	-	-	100	-	-

Sketch Showing How Opacity Varied With Time:



---

(1) Two observers made simultaneous readings, the greater of their readings is reported.

TABLE 4
FACILITY A2
Summary of Results

Run Number	1	2	3	Average
Date	6/10/74	6/11/74	6/12/74	-
Test Time - Minutes	400	320	240	320
Production Rate - TPH (1)	965	1023	1056	1015
Stack Effluent				
Flow rate - ACFM	15797	15771	15866	15811
Flow rate - DSCFM	13368	13246	13196	13270
Temperature - °F	90.0	90.0	94.0	91.3
Water vapor - Vol. %	1.4	2.1	2.5	2.0
Visible Emissions at Collector Discharge - % Opacity		SEE TABLE 5		
Particulate Emissions (2)				
Probe and filter catch				
gr/DSCF	0.00176	0.00188	0.00222	0.00195
gr/ACF	0.00149	0.00158	0.00184	0.00164
lb/hr	0.20	0.21	0.25	0.22
lb/ton	0.00021	0.00024	0.00024	0.00023
Total catch (3)				
gr/DSCF	-	0.00235	0.00314	0.00275
gr/ACF	-	0.00197	0.00261	0.00224
lb/hr	-	0.27	0.36	0.32
lb/ton	-	0.00030	0.00034	0.00032

(1) Throughput through primary crusher.
(2) All three test runs were over-isokinetic.
(3) Back-half sample for run number 1 was lost.

TABLE 5

FACILITY A2

Summary of Visible Emissions(1)

Date: 6/10/74 - 6/11/74

Type of Plant: Crushed Stone - Primary Screen

Type of Discharge: Stack

Distance from Observer to Discharge Point: 60 ft.

Location of Discharge: Baghouse

Height of Observation Point: Ground-level

Height of Point of Discharge: 10 ft.

Direction of Observer from Discharge Point: East

Description of Background: Sky

Description of Sky: Clear

Wind Direction: Southwest

Wind Velocity: 0 - 2 mi/hr.

Color of Plume: None

Detached Plume: No

Duration of Observation: 6/10/74 - 192 minutes
6/11/74 - 36 minutes

SUMMARY OF AVERAGE OPACITY(1)

Set Number	Time		Opacity	
	Start	End	Sum	Average
1 through 11	10:35	11:41	0	0
12 through 32	12:30	2:36	0	0
33 through 38	9:40	10:16	0	0

Readings were 0 percent opacity during all periods of observation.

(1) Two observers made simultaneous readings.

TABLE 6
FACILITY A3
Summary of Results

Run Number	1	2	3	Average
Date	6/10/74	6/11/74	6/12/74	-
Test Time - Minutes	360	288	288	312
Process Weight Rate - TPH	910	915	873	899
Stack Effluent				
Flow rate - ACFM	2303	2313	2422	2346
Flow rate - DSCFM	1900	1902	2003	1935
Temperature - °F	98.0	101.0	97.0	98.7
Water vapor - Vol. %	2.4	2.4	2.3	2.4
Visible Emissions at Collector Discharge - Fugitive (% Opacity)		SEE TABLES 7		
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.00095	0.00162	0.00207	0.00155
gr/ACF	0.00078	0.00134	0.00171	0.00128
lb/hr	0.02	0.03	0.04	0.03
lb/ton	0.00002	0.00003	0.00004	0.00003
Total catch (1)				
gr/DSCF	-	0.00190	0.00259	0.00224
gr/ACF	-	0.00156	0.00214	0.00185
lb/hr	-	0.03	0.04	0.035
lb/ton	-	0.00003	0.00005	0.00004

(1) Back-half sample for run number 1 was lost.

TABLE 7
FACILITY A3
Summary of Visible Emissions(1)

Date: 6/11/74

Type of Plant: Crushed Stone - Conveyor Transfer Point

Type of Discharge: Stack

Distance from Observer to Discharge Point: 60 ft.

Location of Discharge: Baghouse

Height of Observation Point: Ground-level

Height of Point of Discharge: 8 ft.

Direction of Observer from Discharge Point: North

Description of Background: Grey apparatus

Description of Sky: Clear

Wind Direction: Westerly

Wind Velocity: 0 - 10 mi/hr.

Color of Plume: None

Detached Plume: No

Duration of Observation: 240 minutes

SUMMARY OF AVERAGE OPACITY(1)

Set Number	Time		Opacity	
	Start	End	Sum	Average
1 through 30	10:40	1:40	0	0
31 through 40	1:45	2:45	0	0

Readings were 0 percent opacity during all periods of observation.

(1) Two observers made simultaneous readings.

TABLE 8
FACILITY A4
Summary of Results

Run Number	1	2	3	Average
Date	6/6/74	6/7/74	6/8/74	-
Test Time - Minutes	320	320	320	320
Production Rate - TPH	170	162	152	163
Stack Effluent				
Flow rate - ACFM	10579	9971	11045	10532
Flow rate - DSCFM	9277	8711	9656	9214
Temperature - °F	81.0	77.0	80.0	79.3
Water vapor - Vol. %	2.3	2.2	2.1	2.2
Visible Emissions at Collector Discharge - % Opacity		SEE TABLES 9 & 10		
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.00036	0.00075	0.00074	0.00062
gr/ACF	0.00031	0.00065	0.00065	0.00054
lb/hr	0.03	0.06	0.06	0.05
lb/ton	0.00017	0.00034	0.00041	0.00031
Total catch				
gr/DSCF	0.00047	0.00104	-	0.00678
gr/ACF	0.00041	0.00095	-	0.00068
lb/hr	0.04	0.08	-	0.06
lb/ton	0.00022	0.00050	-	0.00034

TABLE 9

FACILITY A4

Summary of Visible Emissions(1)

Date: 6/6/74

Type of Plant: Crushed Stone - Secondary Crushing and Screening

Type of Discharge: Stack

Distance from Observer to Discharge Point: 100 ft.

Location of Discharge: Baghouse

Height of Observation Point: Ground-level

Height of Point of Discharge: 15 ft.

Direction of Observer from Discharge Point: North

Description of Background: Sky

Description of Sky: Clear

Wind Direction: Variable

Wind Velocity: 0 to 10 mi/hr.

Color of Plume: None

Detached Plume: No

Duration of Observation: 240 minutes

SUMMARY OF AVERAGE OPACITY(1)

Set Number	Time		Opacity	
	Start	End	Sum	Average
1 through 30	10:40	1:40	0	0
31 through 40	1:45	2:45	0	0

Readings were 0 percent opacity during all periods of observation.

(1) Two observers made simultaneous readings.

TABLE 10

FACILITY A 4

SUMMARY OF VISIBLE EMISSIONS (1)

Date: 7/9/75 - 7/10/75

Type of Plant: Crushed stone (cement rock)

Type of Discharge: Fugitive

Location of Discharge: Conveyor (transfer point)

Height of Point of Discharge: 8 feet

Distance from Observer to Discharge Point: 50 feet

Description of Background: Sky

Height of Observation Point: 6 feet

Description of Sky: Partly cloudy

Direction of Observer from Discharge Point: SE

Wind Direction: South

Wind Velocity: 3 - 5 mph

Color of Plume: White

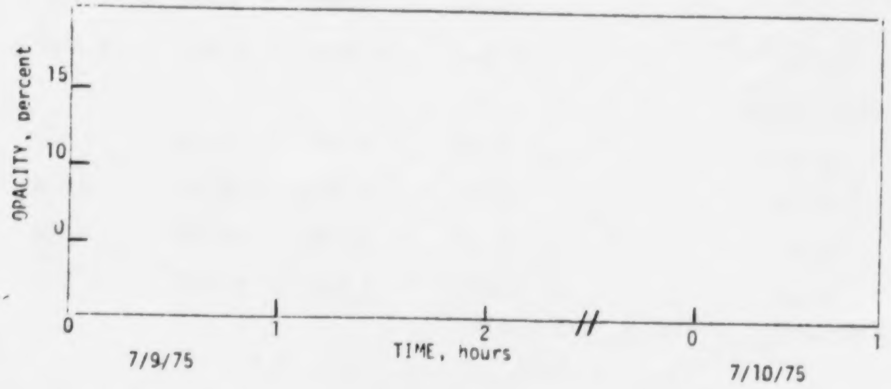
Detached Plume: No

Duration of Observation: 7/9/75 - 106 minutes
7/10/75 - 60 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity Min.	Sec.	Opacity, Percent	Total Time Equal to or Greater Than Given Opacity Min.	Sec.
5	3	0	55	-	-
10	0	45	60	-	-
15	0	30	65	-	-
20	0	0	70	-	-
25	-	-	75	-	-
30	-	-	80	-	-
35	-	-	85	-	-
40	-	-	90	-	-
45	-	-	95	-	-
50	-	-	100	-	-

Sketch Showing How Opacity Varied With Time:



---

(1) Two observers made simultaneous readings, the greater of their readings is reported.

TABLE 11
FACILITY B1
Summary of Results

Run Number	1	2	3	Average
Date	10/29/74	10/30/74	10/30/74	-
Test Time - Minutes	180	120	120	140
Production Rate - TPH(1)	324	359	375	353
Stack Effluent				
Flow rate - ACFM	5154	6121	6078	5784
Flow rate - DSCFM	4998	5896	5753	5549
Temperature - °F	70	76	83	76.3
Water vapor - Vol. %	1.80	1.87	2.06	1.91
Visible Emissions at Collector Discharge - % Opacity		See Table 12		
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.009	0.001	0.010	0.007
gr/ACF	0.012	0.004	0.011	0.009
lb/hr	0.402	0.072	0.500	0.325
lb/ton	0.0012	0.0002	0.0013	0.0007
Total catch				
gr/DSCF	0.009	0.001	0.010	0.007
gr/ACF	0.011	0.003	0.011	0.008
lb/hr	0.496	0.180	0.553	0.408
lb/ton	0.0015	0.0005	0.0015	0.0012

(1) Throughput through primary crusher.

TABLE 12

FACILITY B1

Summary of Visible Emissions(1)

(Observer 1)

Date: 10/29/74 - 10/30/74

Type of Plant: Crushed Stone - Primary Crusher

Type of Discharge: Stack

Distance from Ovserver to Discharge Point: 15 ft.

Location of Discharge: Baghouse

Height of Observation Point: Ground level

Height of Point of Discharge: 25 ft.

Direction of Observer from Discharge Point: West

Description of Background: Grey quarry wall

Description of Sky: Clear to cloudy

Wind Direction: Northwesterly

Wind Velocity: Not available

Color of Plume: White

Detached Plume: No

Duration of Observation: 10/29/74 - 180 minutes
10/30/74 - 234 minutes

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
10/29/74				
1	10:30	10:36	10	0.4
2	10:36	10:42	20	0.8
3	10:42	10:48	25	1.0
4	10:48	10:54	15	0.6
5	10:54	11:00	15	0.6
6	11:00	11:06	5	0.2
7	11:06	11:12	10	0.4
8	11:12	11:18	25	1.0
9	11:18	11:24	20	0.8
10	11:24	11:30	15	0.6
11	11:30	11:36	25	1.0
12	11:36	11:42	30	1.2
13	11:42	11:48	15	0.6
14	1:15	1:21	0	0
15	1:21	1:27	15	0.6
16	1:27	1:33	5	0.2
17	1:33	1:39	5	0.2
18	1:39	1:45	0	0
19	1:45	1:51	0	0
20	1:51	1:57	0	0
21	1:57	2:03	5	0.2
22	2:03	2:09	5	0.2
23	2:09	2:15	0	0
24	2:15	2:21	0	0
25	2:21	2:27	0	0
26	2:27	2:33	5	0.2
27	2:33	2:39	5	0.2
28	2:39	2:45	0	0
29	2:45	2:51	0	0
30	2:51	2:57	10	0.4
10/30/74				
31	9:05	9:11	0	0
32	9:11	9:17	0	0
33	9:17	9:23	0	0
34	9:23	9:29	0	0
35	9:29	9:35	5	0.2
36	9:35	9:41	10	0.4
37	9:41	9:47	0	0
38	9:47	9:53	0	0
39	9:53	9:59	5	0.2
40	9:59	10:05	0	0
41	10:05	10:11	0	0
42	10:11	10:17	0	0
43	10:17	10:23	0	0
44	10:28	10:34	0	0
45	10:34	10:40	10	0.4
46	10:40	10:46	5	0.2
47	10:58	11:04	0	0
48	11:04	11:10	5	0.2
49	11:10	11:16	10	0.4
50	11:24	11:30	0	0
51	11:30	11:36	0	0
52	1:02	1:08	0	0
53	1:08	1:14	0	0
54	1:14	1:20	0	0
55	1:20	1:26	10	0.4
56	1:26	1:32	0	0
57	1:32	1:38	5	0.2
58	1:38	1:44	0	0
59	1:44	1:50	0	0
60	1:50	1:56	0	0
61	1:56	2:02	5	0.2
62	2:02	2:08	0	0
63	2:08	2:14	5	0.2
64	2:14	2:20	5	0.2
65	2:20	2:26	0	0
66	2:26	2:32	0	0
67	2:39	2:45	0	0
68	2:45	2:51	5	0.2
69	2:51	2:57	0	0

TABLE 13

FACILITY B2

Summary of Results

Run Number	1	2	3	Average
Date	10/31/74	10/31/74	11/11/74	-
Test Time - Minutes	108	108	108	108
Production Rate - TPH	270	270	270	270
Stack Effluent				
Flow rate - ACFM	19684	18921	16487	18197
Flow rate - DSCFM	18296	17638	15681	17205
Temperature - °F	92.0	96.0	79.0	87.0
Water vapor - Vol. %	1.95	1.92	2.01	1.96
Visible Emissions at Collector Discharge - % Opacity	SEE TABLES 14 - 23			
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.003	0.005	0.003	0.0037
gr/ACF	0.003	0.005	0.003	0.0037
lb/hr	0.427	0.753	0.457	0.546
lb/ton	0.0016	0.0028	0.0017	0.0020
Total catch				
gr/DSCF	0.006	0.006	0.007	0.0063
gr/ACF	0.005	0.006	0.007	0.0060
lb/hr	0.916	0.978	0.955	0.946
lb/ton	0.0034	0.0036	0.0035	0.0035

TABLE 14
FACILITY B2
Summary of Visible Emissions
(Observer 1)

Date: 10/31/74 - 11/1/74

Type of Plant: Crushed Stone - Secondary and Tertiary Crushing and Screening

Type of Discharge: Stack

Distance from Observer to Discharge Point: 30 ft.

Location of Discharge: Baghouse

Height of Observation Point: 5 ft.

Height of Point of Discharge: 8 ft.

Direction of Observer from Discharge Point: East

Description of Background: Sky

Description of Sky: Clear to partly cloudy

Wind Direction: Southeasterly

Wind Velocity: Not available

Color of Plume: White

Detached Plume: No

Duration of Observation: 10/31/74 -
240 minutes
11/1/74 -
106 minutes

SUMMARY OF AVERAGE OPACITY

		Time		Opacity	
Date	Set Number	Start	End	Sum	Average
10/31/74	1	9:27	9:33	5	0.2
	2	9:33	9:39	10	0.4
	3	9:39	9:45	5	0.2
	4	9:45	9:51	0	0
	5	9:51	9:57	5	0.2
	6	9:57	10:03	5	0.2
	7	10:03	10:09	10	0.4
	8	10:09	10:15	5	0.2
	9	10:15	10:21	20	0.8
	10	10:21	10:27	0	0
	11	10:27	10:33	0	0
	12	10:33	10:39	0	0
	13	10:39	10:45	5	0.2
	14	10:45	10:51	5	0.2
	15	10:51	10:57	10	0.4
	16	10:57	11:03	0	0
	17	11:03	11:09	5	0.2
	18	11:09	11:15	0	0
	19	11:15	11:21	0	0
	20	11:21	11:27	10	0.4
	21 through 40	1:09	3:09	0	0
11/1/74	41 through 56	8:11	9:47	0	0

Readings ranged from 0 to 5 percent opacity.

Table 15

FACILITY B2

SUMMARY OF VISIBLE EMISSIONS

Date: 6/30/75

Type of Plant: Crushed stone (limestone)

Type of Discharge: Fugitive

Location of Discharge: Secondary Cone Crusher (#1)

Height of Point of Discharge: 25 ft.

Distance from Observer to Discharge Point: 45 ft.

Description of Background: Sky & Equipment

Height of Observation Point: 2 ft.

Description of Sky: Clear

Direction of Observer from Discharge Point: North

Wind Direction: East

Wind Velocity: 5-10 mph

Color of Plume: White

Detached Plume: No

Duration of Observation: 231 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opaci	
	Min.	Sec.		Min.	Se
5	23	0	55		
10	0	45	60		
15			65		
20			70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Reproduced from best available copy.

Table 16

FACILITY B2

SUMMARY OF VISIBLE EMISSIONS

Date: 6/30/75

Type of Plant: Crushed stone (limestone)

Type of Discharge: Fugitive

Location of Discharge: Secondary Cone Crusher (#2)

Height of Point of Discharge: 25 ft.

Distance from Observer to Discharge Point: 45 ft.

Description of Background: Sky & Equipment

Height of Observation Point: 2 ft.

Description of Sky: Clear

Direction of Observer from Discharge Point: North

Wind Direction: East

Wind Velocity: 5-10 mph

Color of Plume: White

Detached Plume: No

Duration of Observation: 231 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity Min.	Sec.	Opacity, Percent	Total Time Equal to or Greater Than Given Opacity Min.	Sec.
5	0	15	55		
10	0	0	60		
15	-	-	65		
20			70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Table 17

FACILITY B2

SUMMARY OF VISIBLE EMISSIONS

Date: 6/30/75

Type of Plant: Crushed stone (limestone)

Type of Discharge: Fugitive

Location of Discharge: Secondary Cone Crusher (#3)

Height of Point of Discharge: 25 ft.

Distance from Observer to Discharge Point: 45 ft.

Description of Background: Sky & Equipment

Height of Observation Point: 2 ft.

Description of Sky: Clear

Direction of Observer from Discharge Point: North

Wind Direction: East

Wind Velocity: 5-10 mph

Color of Plume: White

Detached Plume: No

Duration of Observation: 231 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.		Min.	Sec.
5	0	0	55		
10	-	-	60		
15			65		
20			70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Table 18

FACILITY B2

SUMMARY OF VISIBLE EMISSIONS

Date: 6/30/75 - 7/1/75

Type of Plant: Crushed stone (limestone)

Type of Discharge: Fugitive

Location of Discharge: Surge Bin

Height of Point of Discharge:

Distance from Observer to Discharge Point: 150 ft

Description of Background: Sky & Equipment

Height of Observation Point: 15 ft.

Description of Sky: Clear

Direction of Observer from Discharge Point: SE

Wind Direction: South

Wind Velocity: 5 mph

Color of Plume: White

Detached Plume: No

Duration of Observation: 6/30/74 - 234 minutes
7/1/75 - 53 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.		Min.	Sec.
5	2	0	55		
10	1	15	60		
15	-	30	65		
20	-	-	70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Table 19

FACILITY B2

SUMMARY OF VISIBLE EMISSIONS

Date: 6/30/75 - 7/1/75

Type of Plant: Crushed stone (limestone)

Type of Discharge: Fugitive

Location of Discharge: Scalping screen

Height of Point of Discharge: 50 ft.	Distance from Observer to Discharge Point: 150 ft.
Description of Background: Sky & Equipment	Height of Observation Point: 15 ft.
Description of Sky: Clear	Direction of Observer from Discharge Point: SE
Wind Direction: South	Wind Velocity: 5 MPH
Color of Plume: White	Detached Plume: no

Duration of Observation: 6/30/75 - 234 minutes
7/1/75 - 53 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.		Min.	Sec.
5	44	45	55		
10	9	45	60		
15	3	0	65		
20	0	30	70		
25	-	-	75		
30			80		
35			85		
40			90		
45			95		
50			100		

Table 20

FACILITY B2

SUMMARY OF VISIBLE EMISSIONS

Date: 6/30/75 - 7/1/75

Type of Plant: Crushed stone (limestone)

Type of Discharge: Fugitive

Location of Discharge: Hammermill

Height of Point of Discharge:

Distance from Observer to Discharge Point: 150 f

Description of Background: Sky & Equipment

Height of Observation Point: 15 ft.

Description of Sky: Clear

Direction of Observer from Discharge Point: SE

Wind Direction: South

Wind Velocity: 5 mph

Color of Plume: White

Detached Plume: No

Duration of Observation: 6/30/75 - 234 minutes
7/1/75 - 53 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.		Min.	Sec.
5			55		
10	0	0	60		
15	-	-	65		
20			70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Table 21

FACILITY B2

SUMMARY OF VISIBLE EMISSIONS

Date: 7/1/75

Type of Plant: Crushed stone (limestone)

Type of Discharge: Fugitive

Location of Discharge: (3-Deck) Finishing Screen (left)

Height of Point of Discharge: 40

Distance from Observer to Discharge Point: 75 ft.

Description of Background: Hazy Sky

Height of Observation Point: Ground level

Description of Sky: Clear

Direction of Observer from Discharge Point: West

Wind Direction: Southeast

Wind Velocity: 5-15 mph

Color of Plume: White

Detached Plume: No

Duration of Observation: 107 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.		Min.	Se
5	4	30	55		
10	-	-	60		
15			65		
20			70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Table 22

FACILITY B2

SUMMARY OF VISIBLE EMISSIONS

Date: 7/1/75

Type of Plant: Crushed stone (limestone)

Type of Discharge: Fugitive

Location of Discharge: (3-Deck) Finishing screen (right)

Height of Point of Discharge: 40 ft.

Distance from Observer to Discharge Point: 75 ft.

Description of Background: Hazy sky

Height of Observation Point: Ground level

Description of Sky: Clear

Direction of Observer from Discharge Point: West

Wind Direction: Southeast

Wind Velocity: 5-15 mph

Color of Plume: White

Detached Plume: No

Duration of Observation: 107 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.		Min.	Sec.
5	0	15	55		
10	-	-	60		
15			65		
20			70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Table 23

FACILITY B2

SUMMARY OF VISIBLE EMISSIONS

Date: 6/30/75

Type of Plant: Crushed stone (limestone)

Type of Discharge: Fugitive

Location of Discharge: Two (3-Deck) finishing screens

Height of Point of Discharge: 50 ft.

Distance from Observer to Discharge Point: 75 ft.

Description of Background: Hazy sky

Height of Observation Point: Ground level

Description of Sky: Clear

Direction of Observer from Discharge Point: West

Wind Direction: Southeast

Wind Velocity: 10-15 mph

Color of Plume: White

Detached Plume: No

Duration of Observation: 120 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity Min.	Sec.	Opacity, Percent	Total Time Equal to or Greater Than Given Opacity Min.	Sec.
5	86	15	55		
10	28	15	60		
15	5	30	65		
20	0	15	70		
25	0	0	75		
30	-	-	80		
35			85		
40			90		
45			95		
50			100		

TABLE 24
FACILITY B3
Summary of Results

Run Number	1	2	3	Average
Date	10/31/74	11/1/74	11/1/74	-
Test Time - Minutes				
Production Rate - TPH	270	270	270	270
Stack Effluent				
Flow rate - ACFM	18674	18405	16238	17772
Flow rate - DSCFM	17335	17186	15466	16662
Temperature - °F	92	90	79	87
Water Vapor - Vol. %	2.13	1.73	1.87	1.91
Visible Emissions at Collector Discharge - % Opacity				
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.002	0.004	0.003	0.003
gr/ACF	0.002	0.004	0.003	0.003
lb/hr	0.355	0.614	0.411	0.460
lb/ton	0.0013	0.0023	0.0015	0.0017
Total catch(1)				
gr/DSCF				
gr/ACF				
lb/hr				
lb/ton				

(1) No analysis of bark-half on in-stack filter tests.

TABLE 25
FACILITY C1
Summary of Results

Run Number	1	2	3	Average
Date	11/19/74	11/21/74	11/22/74	-
Test Time - Minutes	120	240	240	200
Production Rate - TPH(1)				
Stack Effluent				
Flow rate - ACFM	7340	7560	7520	7473
Flow rate - DSCFM	7250	7720	7800	7593
Temperature - °F	66.0	38.0	44.0	49.3
Water vapor - Vol. %	1.0	0.4	0.1	0.5
Visible Emissions at Collector Discharge - % Opacity	See table 26			
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.003	0.0007	0.003	0.0022
gr/ACF	0.003	0.0007	0.003	0.0022
lb/hr	0.18	0.05	0.17	0.10
lb/ton	0.001	0.0004	0.001	0.0008
Total catch				
gr/DSCF	0.007	0.001	0.003	0.0037
gr/ACF	0.007	0.001	0.003	0.0037
lb/hr	0.43	0.09	0.21	0.24
lb/ton	0.003	0.0008	0.002	0.0019

(1) Throughput through primary crusher.

TABLE 23
FACILITY C1
Summary of Visible Emissions(1)

Date: 11/21/74

Type of Plant: Crushed Stone - Primary and Secondary Crushing and Screening

Type of Discharge: Stack

Location of Discharge: Baghouse

Height of Point of Discharge: 40 ft.

Description of Background: Dark Woods

Description of Sky: Overcast

Wind Direction: Easterly

Color of Plume: White

Duration of Observation: 240 minutes

Distance from Observer to Discharge Point: 100 ft.

Height of Observation Point: 50 ft.

Direction of Observer from Discharge Point: N.W.

Wind Velocity: 10 to 30 mi/hr.

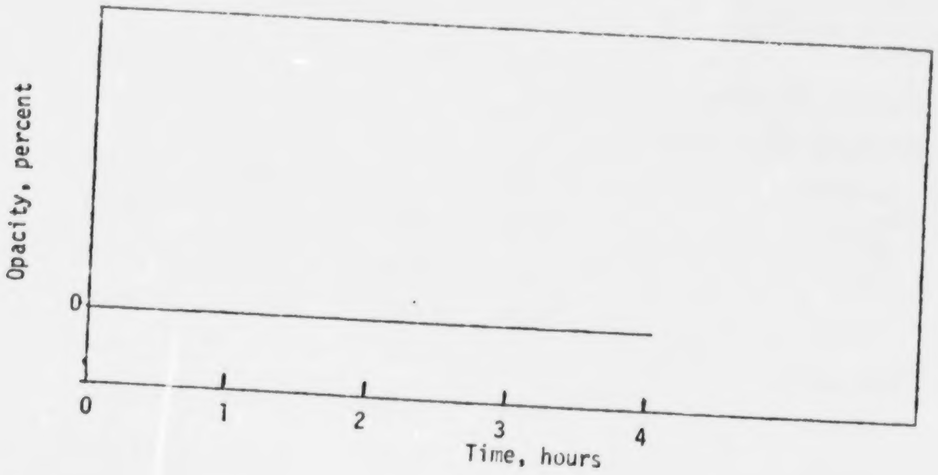
Detached Plume: No

SUMMARY OF AVERAGE OPACITY(2)

Set Number	Time		Opacity	
	Start	End	Sum	Average
1 through 40	12:10	4:10	0	0

Readings were 0 percent opacity during the observation period.

Sketch Showing How Opacity Varied With Time:



(1) Two observers made simultaneous readings.

Reference 5.

Reproduced from best available copy.

TABLE 27
FACILITY C2
Summary of Results

Run Number	1	2	3	Average
Date	11/19/74	11/21/74	11/22/74	-
Test Time - Minutes	120	240	240	200
Production Rate - TPH(1)	132	119	127	126
Stack Effluent				
Flow rate - ACFM	6220	6870	6540	6543
Flow rate - DSCFM	6260	6880	6700	6613
Temperature - °F	62.0	50.0	51.0	54.3
Water vapor - Vol. %	0.4	0.3	0.1	0.27
Visible Emissions at Collector Discharge - % Opacity	See Table 28			
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.006	0.00003	0.0004	0.00214
gr/ACF	0.006	0.00003	0.004	0.00214
lb/hr	0.31	0.002	0.02	0.111
lb/ton	0.002	0.00002	0.0002	0.00074
Total catch				
gr/DSCF	0.008	0.0006	0.0009	0.0032
gr/ACF	0.009	0.0007	0.001	0.0057
lb/hr	0.46	0.04	0.05	0.18
lb/ton	0.003	0.0003	0.0004	0.0012

(1) Throughput through primary crusher.

TABLE 28

FACILITY C2

Summary of Visible Emissions

Date: 11/21/74

Type of Plant: Crushed Stone - Finishing Screens

Type of Discharge: Stack

Location of Discharge: Baghouse

Height of Point of Discharge: 40 ft.

Description of Background: Dark woods

Description of Sky: Overcast

Wind Direction: Easterly

Color of Plume: White

Duration of Observation: 240 minutes

Distance from Observer to Discharge Point: 200 ft

Height of Observation Point: 50 ft.

Direction of Observer from Discharge Point: N.W.

Wind Velocity: 10 to 30 mi/hr.

Detached Plume: ——

SUMMARY OF AVERAGE OPACITY

Set Number	Time		Opacity	
	Start	End	Sum	Average
1 through 40	12:10	4:10	0	0

Readings were 0 percent opacity during the observation period.

Sketch Showing How Opacity Varied With Time:

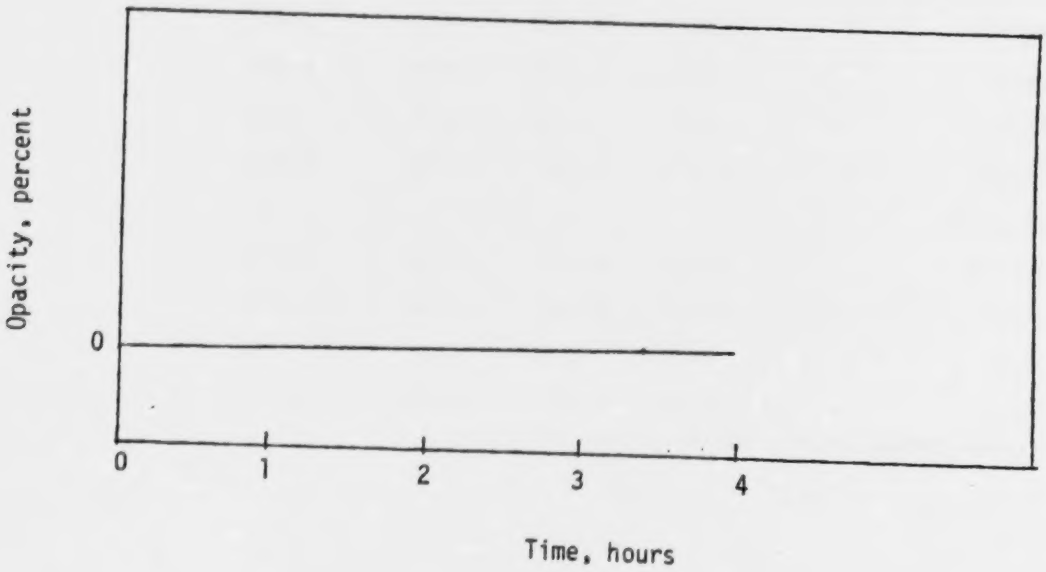


TABLE 29
FACILITY D1
Summary of Results

Run Number	1	2	3	Average
Date	9/17/74	9/18/74	9/19/74	-
Test Time - Minutes	240	240	240	240
Production Rate - TPH(1)	225	230	220	225
Stack Effluent				
Flow rate - ACFM	31830	31810	31950	31863
Flow rate - DSCFM	31370	30650	31230	31083
Temperature - °F	66.0	71.0	68.0	68.3
Water vapor - Vol. %	1.2	1.7	1.6	1.5
Visible Emissions at Collector Discharge - % Opacity		SEE TABLES 30-36		
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.0095	0.0081	0.0080	0.0085
gr/ACF	0.0094	0.0078	0.0078	0.0083
lb/hr	2.55	2.13	2.13	2.27
lb/ton	0.0113	0.0093	0.0097	0.0101
Total catch				
gr/DSCF	0.0100	0.0085	0.0086	0.0090
gr/ACF	0.0096	0.0082	0.0084	0.0088
lb/hr	2.69	2.23	2.30	2.41
lb/ton	0.0120	0.0097	0.0105	0.107

(1) Throughput through primary crusher.

TABLE 30

FACILITY U1

Summary of Visible Emissions$^{(1)}$

Date: 9/17/74

Type of Plant: Crushed Stone - Secondary and Tertiary Crushing & Screening

Type of Discharge: Stack

Distance from Observer to Discharge Point: 300 ft.

Location of Discharge: Baghouse

Height of Observation Point: 40 ft.

Height of Point of Discharge: 55 ft.

Direction of Observer from Discharge Point: S.E.

Description of Background: Trees

Description of Sky: Partly Cloudy

Wind Direction: Northerly

Wind Velocity: 5 - 10 mi/hr.

Color of Plume: None

Detached Plume: No

Duration of Observation: 240 minutes

SUMMARY OF AVERAGE OPACITY$^{(2)}$

Set Number	Time		Opacity	
	Start	End	Sum	Average
1 through 40	9:10	1:00	0	0

Readings were 0 percent opacity during the period of observation.

Sketch Showing How Opacity Varied With Time:

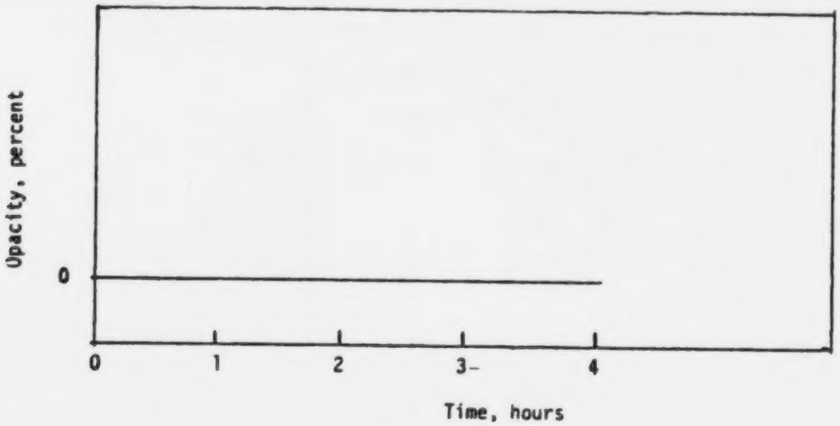


Table 31

FACILITY D1

SUMMARY OF VISIBLE EMISSIONS

Date: 7/8/75

Type of Plant: Crushed stone (traprock)

Type of Discharge: Fugitive

Location of Discharge: Tertiary gyrasphere cone crusher (S)

Height of Point of Discharge:

Distance from Observer to Discharge Point: 30 ft.

Description of Background: Machinery

Height of Observation Point: ground level

Description of Sky: Overcast

Direction of Observer from Discharge Point: West

Wind Direction: Southwest

Wind Velocity: 0-10 mph

Color of Plume: White

Detached Plume: No

Duration of Observation: 170 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.		Min.	Sec.
5	0	0	55		
10	-	-	60		
15			65		
20			70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Table 32

FACILITY D1

SUMMARY OF VISIBLE EMISSIONS

Date: 7/8/75

Type of Plant: Crushed stone (traprock)

Type of Discharge: Fugitive

Location of Discharge: Tertiary gyrashere cone crusher (N)

Height of Point of Discharge:

Distance from Observer to Discharge Point: 30 ft

Description of Background: Machinery

Height of Observation Point: ground level

Description of Sky: Overcast

Direction of Observer from Discharge Point: West

Wind Direction: Southwest

Wind Velocity: 0-10 mph

Color of Plume: White

Detached Plume: No

Duration of Observation: 170 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.
5	0	0
10	-	-
15		
20		
25		
30		
35		
40		
45		
50		

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.
55		
60		
65		
70		
75		
80		
85		
90		
95		
100		

Table 33

FACILITY D1

SUMMARY OF VISIBLE EMISSIONS

Date: 7/8/75

Type of Plant: Crushed stone (traprock)

Type of Discharge: Fugitive

Location of Discharge: Secondary standard cone crusher

Height of Point of Discharge:

Distance from Observer to Discharge Point: 30 ft.

Description of Background: Machinery

Height of Observation Point: Ground level

Description of Sky: Overcast

Direction of Observer from Discharge Point: West

Wind Direction: Southwest

Wind Velocity: 0-10 mph

Color of Plume: White

Detached Plume: No

Duration of Observation: 170 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.
5	0	0
10	-	-
15		
20		
25		
30		
35		
40		
45		
50		
55		
60		
65		
70		
75		
80		
85		
90		
95		
100		

Table 34

FACILITY D1

SUMMARY OF VISIBLE EMISSIONS

Date: 7/9/75

Type of Plant: Crushed stone (traprock)

Type of Discharge: Fugitive

Location of Discharge: Scalping screen

Height of Point of Discharge:

Distance from Observer to Discharge Point: 30 ft.

Description of Background: Equipment

Height of Observation Point: 15 ft.

Description of Sky: Overcast

Direction of Observer from Discharge Point: North

Wind Direction: Southwest

Wind Velocity: 0-10 mph

Color of Plume: White

Detached Plume: No

Duration of Observation: 210 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.
5	0	0
10	-	-
15		
20		
25		
30		
35		
40		
45		
50		
55		
60		
65		
70		
75		
80		
85		
90		
95		
100		

Reproduced from
best available copy.

Table 35

FACILITY D1

SUMMARY OF VISIBLE EMISSIONS

Date: 7/9/75

Type of Plant: Crushed stone (traprock)

Type of Discharge: Fugitive

Location of Discharge: Secondary (2-Deck) sizing screens

Height of Point of Discharge:

Distance from Observer to Discharge Point: 30 ft.

Description of Background: Equipment

Height of Observation Point: 15 ft.

Description of Sky: Overcast

Direction of Observer from Discharge Point: North

Wind Direction: Southwest

Wind Velocity: 0-10 mph

Color of Plume: White

Detached Plume: No

Duration of Observation: 210 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.		Min.	Sec.
5	0	0	55		
10	-	-	60		
15			65		
20			70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Table 36

FACILITY D1

SUMMARY OF VISIBLE EMISSIONS

Date: 7/9/75

Type of Plant: Crushed stone (traprock)

Type of Discharge: Fugitive

Location of Discharge: Secondary (3-Deck) sizing screens

Height of Point of Discharge:

Distance from Observer to Discharge Point: 30 f

Description of Background: Equipment

Height of Observation Point: 15 ft.

Description of Sky: Overcast

Direction of Observer from Discharge Point: Nort

Wind Direction: Southwest

Wind Velocity: 0-10 mph

Color of Plume: White

Detached Plume: No

Duration of Observation: 210 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.
5	0	0
10	-	-
15		
20		
25		
30		
35		
40		
45		
50		
55		
60		
65		
70		
75		
80		
85		
90		
95		
100		

TABLE 37
FACILITY D2
Summary of Results

Run Number	1	2	3	Average
Date	9/17/74	9/18/74	9/19/74	-
Test Time - Minutes	240	240	240	240
Production Rate - TPH(1)	225	230	220	225
Stack Effluent				
Flow rate - ACFM	26790	26260	24830	25960
Flow rate - DSCFM	26200	25230	24170	25200
Temperature - °F	69.0	74.0	72.0	71.7
Water vapor - Vol. %	1.3	1.6	1.3	1.4
Visible Emissions at Collector Discharge - % Opacity	See Table 38			
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.0027	0.0038	0.0023	0.0029
gr/ACF	0.0027	0.0036	0.0022	0.0028
lb/hr	0.61	0.82	0.47	0.63
lb/ton	0.0027	0.0036	0.0021	0.0028
Total catch				
gr/DSCF	0.0041	0.0045	0.0031	0.0039
gr/ACF	0.0040	0.0043	0.0030	0.0038
lb/hr	0.91	0.98	0.64	0.84
lb/ton	0.0040	0.0043	0.0029	0.0037

(1) Throughput through primary crusher.

TABLE 38

FACILITY D2

Summary of Visible Emissions(1)

Date: 9/18/74

Type of Plant: Crushed Stone - Finishing Screens

Type of Discharge: Stack

Location of Discharge: Baghouse

Height of Point of Discharge: 55 ft.

Description of Background: Trees

Description of Sky: Clear

Wind Direction: Northerly

Color of Plume: None

Duration of Observation: 240 minutes

Distance from Observer to Discharge Point: 300 ft.

Height of Observation Point: 40 ft.

Direction of Observer from Discharge Point: North

Wind Velocity: 5 to 10 mi/hr.

Detached Plume: No

SUMMARY OF AVERAGE OPACITY(2)

Set Number	Time		Opacity	
	Start	End	Sum	Average
1 through 40	8:30	12:30	0	0

Readings were 0 percent opacity during period of observation.

Sketch Showing How Opacity Varied with Time:

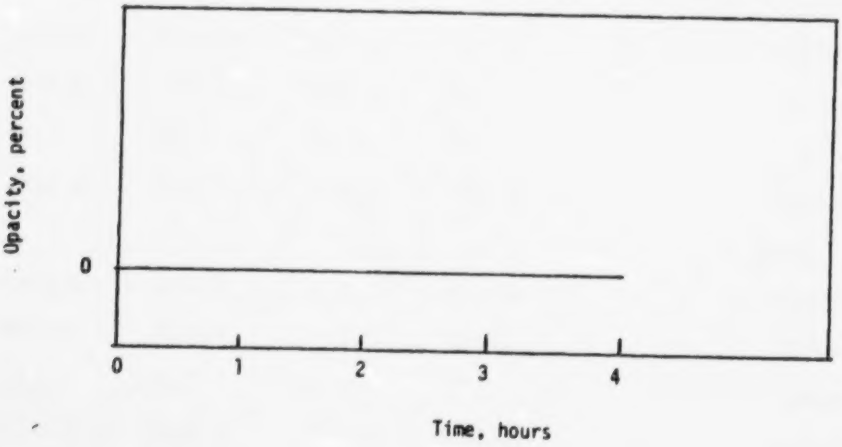


TABLE 39
FACILITY E1
Summary of Results

Run Number	1	2	3	Average
Date	11/18/74	11/18/74	11/19/74	-
Test Time - Minutes	120	120	120	120
Production Rate - TPH(1)	384	342	460	395
Stack Effluent				
Flow rate - ACFM	15272	13997	14975	14748
Flow rate - DSCFM	16297	14796	15642	15578
Temperature - °F	33.1	40.4	41.0	38.2
Water vapor - Vol. %	0.5	0.0	0.5	0.3
Visible Emissions at Collector Discharge - % Opacity	SEE TABLE 40			
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.0134	0.0116	0.0147	0.0132
gr/ACF	0.0143	0.0122	0.0154	0.0140
lb/hr	1.87	1.47	1.97	1.77
lb/ton	0.0049	0.0043	0.0043	0.0045
Total catch				
gr/DSCF	0.0170	0.0137	0.0164	0.0157
gr/ACF	0.0181	0.0145	0.0171	0.0166
lb/hr	2.37	1.74	2.20	2.10
lb/ton	0.0067	0.0051	0.0048	0.0055

(1) Throughput through primary crusher.

TABLE 40

FACILITY E1

Summary of Visible Emissions[1]

Date: 11/18/74 - 11/19/74

Type of Plant: Crushed Stone - Tertiary Crushing and Screening

Type of Discharge: Stack

Distance from Observer to Discharge Point: 60 ft.

Location of Discharge: Baghouse

Height of Observation Point: Ground level

Height of Point of Discharge: 1/2 ft.

Direction of Observer from Discharge Point: South

Description of Background: Grey Wall

Description of Sky: Overcast

Wind Direction: Westerly

Wind Velocity: 2 - 10 mi/hr.

Color of Plume: None

Detached Plume: No

Duration of Observation: 11/18/74 - 120 minutes
11/19/74 - 60 minutes

SUMMARY OF AVERAGE OPACITY

Set Number	Time		Opacity	
	Start	End	Sum	Average
11/18/74				
1 through 10	9:00	10:00	0	0
11 through 20	10:15	11:15	0	0
11/19/74				
21 through 30	10:07	11:07	0	0

Readings were 0 percent opacity during all periods of observation.

Sketch Showing How Opacity Varied With Time:

TABLE 41

FACILITY E2

Summary of Results

Run Number	1	2	3	Average
Date	11/18/74	11/18/74	11/19/74	-
Test Time - Minutes	120	120	120	120
Production Rate - TPH(1)	384	342	460	395
Stack Effluent				
Flow rate - ACFM	22169	19772	21426	21122
Flow rate - DSCFM	23001	19930	21779	21570
Temperature - °F	44.5	59.2	55.0	52.9
Water vapor - Vol. %	1.1	1.1	0.6	0.9
Visible Emissions at Collector Discharge - % Opacity		SEE TABLE 42		
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.0132	0.0096	0.0153	0.0127
gr/ACF	0.0137	0.0097	0.0155	0.0130
lb/hr	2.60	1.65	2.85	2.37
lb/ton	0.0068	0.0048	0.0062	0.0059
Total catch				
gr/DSCF	0.0205	0.1378	0.0170	0.0171
gr/ACF	0.0213	0.0139	0.0173	0.0175
lb/hr	4.05	2.35	3.18	3.19
lb/ton	0.0105	0.0069	0.0069	0.0081

(1) Throughput through primary crusher.

TABLE 42

FACILITY E2

Summary of Visible Emissions(1)

Date: 11/18/74 - 11/19/74

Type of Plant: Crushed Stone - Finishing Screens and Bins

Type of Discharge: Stack

Distance from Observer to Discharge Point: 120 ft

Location of Discharge: Baghouse

Height of Observation Point: Ground level

Height of Point of Discharge: 1/2 ft.

Direction of Observer from Discharge Point: South

Description of Background: Hillside

Description of Sky: Clear

Wind Direction: Westerly

Wind Velocity: 2 - 10 mi/hr.

Color of Plume: None

Detached Plume: No

Duration of Observation: 11/18/74 - 120 minutes
11/19/74 - 60 minutes

SUMMARY OF AVERAGE OPACITY(2)

Set Number	Time Start	Time End	Opacity Sum	Opacity Average
11/18/74				
1 through 10	12:50	1:50	0	0
11 through 20	1:50	2:00	0	0
11/19/74				
21 through 30	9:05	10:05	0	0

Readings were 0 percent opacity during all periods of observation.

Sketch Showing How Opacity Varied With Time:

Table 43

FACILITY F

SUMMARY OF VISIBLE EMISSIONS

Date: 8/26/76

Type of Plant: Crushed stone (traprock)

Type of Discharge: Fugitive

Location of Discharge: Two tertiary crushers (#4 and #5)

Height of Point of Discharge: #4-20 ft.
#5-10 ft.

Distance from Observer to Discharge Point: 100 ft.

Description of Background: Gray equipment Structures

Height of Observation Point: ground level

Description of Sky: Partly cloudy

Direction of Observer from Discharge Point: West

Wind Direction: Variable

Wind Velocity: 0-5 mph

Color of Plume: No visible plume

Detached Plume:

Duration of Observation: 65 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.
5	0	0
10	-	-
15		
20		
25		
30		
35		
40		
45		
50		

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.
55		
60		
65		
70		
75		
80		
85		
90		
95		
100		

Table 44

FACILITY F

SUMMARY OF VISIBLE EMISSIONS

Date: 8/26/76

Type of Plant: Crushed stone (traprock)

Type of Discharge: Fugitive

Location of Discharge: Four processing screens

Height of Point of Discharge: 50 ft.	Distance from Observer to Discharge Point: 100 ft
Description of Background: gray walls	Height of Observation Point: ground level
Description of Sky: Partly cloudy	Direction of Observer from Discharge Point: NE
Wind Direction: Variable	Wind Velocity: 0-5 mph
Color of Plume: No visible plume	Detached Plume:

Duration of Observation: 180 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.		Min.	Sec.
5	0	0	55		
10	-	-	60		
15			65		
20			70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Table 45

FACILITY F

SUMMARY OF VISIBLE EMISSIONS

Date: 8/27/76

Type of Plant: Crushed stone (traprock)

Type of Discharge: Fugitive

Location of Discharge: Conveyor transfer points

Height of Point of Discharge: 75 ft.

Distance from Observer to Discharge Point: 150 ft.

Description of Background: Gray equipment structures

Height of Observation Point: 50 ft.

Description of Sky: Overcast

Direction of Observer from Discharge Point: SE

Wind Direction: Variable, S-SE

Wind Velocity: 0-10 mph

Color of Plume: No visible plume

Detached Plume:

Duration of Observation: 179 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.		Min.	Se
5	0	0	55		
10	-	-	60		
15			65		
20			70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Reproduced from
best available copy.

Table 46

FACILITY G1

SUMMARY OF VISIBLE EMISSIONS

Date: 9/27/76

Type of Plant: Feldspar

Type of Discharge: Fugitive

Location of Discharge: Primary Crusher

Height of Point of Discharge: 10-30 ft.

Distance from Observer to Discharge Point: 100 ft

Description of Background: Quarry wall & equipment structures

Height of Observation Point: Ground level

Description of Sky: Partly cloudy

Direction of Observer from Discharge Point: S

Wind Direction: Northeast

Wind Velocity: 0-10 mph

Color of Plume:

Detached Plume: No

Duration of Observation: 60 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity Min.	Sec.	Opacity, Percent	Total Time Equal to or Greater Than Given Opacity Min.	Sec.
5	0	45	55		
10	-	-	60		
15			65		
20			70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Table 47

FACILITY G1

SUMMARY OF VISIBLE EMISSIONS

Date: 9/27/76

Type of Plant: Feldspar

Type of Discharge: Fugitive

Location of Discharge: Conveyor transfer point (#1)

Height of Point of Discharge: 10 ft.

Distance from Observer to Discharge Point: 50 ft.

Description of Background: Quarry wall

Height of Observation Point: ground level

Description of Sky: Overcast

Direction of Observer from Discharge Point: SE

Wind Direction: Northeast

Wind Velocity: 0-5 mph

Color of Plume: No plume

Detached Plume: No

Duration of Observation: 80 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.		Min.	Sec.
5	0	0	55		
10	-	-	60		
15			65		
20			70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Reproduced from best available copy.

Table 48

FACILITY G1

SUMMARY OF VISIBLE EMISSIONS

Date: 9/27/76

Type of Plant: Feldspar

Type of Discharge: Fugitive

Location of Discharge: Conveyor transfer point (#2)

Height of Point of Discharge: 40 ft.

Distance from Observer to Discharge Point: 50 ft

Description of Background: Quarry wall

Height of Observation Point: ground level

Description of Sky: Partly cloudy-Overcast

Direction of Observer from Discharge Point: SE

Wind Direction: North-northwest

Wind Velocity: 0-10 mph

Color of Plume: No plume

Detached Plume: N/A

Duration of Observation: 87 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.		Min.	Sec.
5	0	0	55		
10	-	-	60		
15			65		
20			70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Table 49

FACILITY G1

SUMMARY OF VISIBLE EMISSIONS

Date: 9/27/76

Type of Plant: Feldspar

Type of Discharge: Fugitive

Location of Discharge: Secondary crusher

Height of Point of Discharge: 10-20 ft.

Distance from Observer to Discharge Point: 75 ft

Description of Background: Equipment structure

Height of Observation Point: 75 ft

Description of Sky: Partly cloudy -cloudy

Direction of Observer from Discharge Point: SSE

Wind Direction: Northwest

Wind Velocity: 0-7 mph

Color of Plume: No visible plume

Detached Plume: N/A

Duration of Observation: 1 hour

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity Min.	Sec.	Opacity, Percent	Total Time Equal to or Greater Than Given Opacity Min.	Sec.
5	0	0	55		
10	-	-	60		
15			65		
20			70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Table 50

FACILITY G1

SUMMARY OF VISIBLE EMISSIONS

Date: 9/27/76

Type of Plant: Feldspar

Type of Discharge: Fugitive

Location of Discharge: Conveyor transfer Point (#4)

Height of Point of Discharge: 10 ft.

Distance from Observer to Discharge Point: 84 ft.

Description of Background: cliff or wall

Height of Observation Point: 75 ft.

Description of Sky: cloudy

Direction of Observer from Discharge Point: SE

Wind Direction: North

Wind Velocity: 0-7 mph

Color of Plume: No visible plume

Detached Plume: N/A

Duration of Observation: 84 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.
5	0	0
10	-	-
15		
20		
25		
30		
35		
40		
45		
50		

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.
55		
60		
65		
70		
75		
80		
85		
90		
95		
100		

Reproduced from best available copy.

Table 51
FACILITY G2

Summary of Results

Run Number	1	2	3	Average
Date	9/28/76	9/28/76	9/29/76	
Test Time-minutes	120	120	120	120
Production rate - TPH				
Stack Effluent				
Flow rate - ACFM	5070	4830	4470	4790
Flow rate - DSCFM	4210	3940	3720	3960
Temperature - °F	105	115	103	108
Water vapor - Vol.%				
Visible Emissions at Collector Discharge - Percent Opacity	See Tables 52 - 61			
Particulate Emissions				
Probe and Filter Catch				
gr/DSCF	0.005	0.005	0.004	0.005
gr/ACF	0.004	0.004	0.004	0.004
lb/hr	0.17	0.18	0.14	0.16
lb/ton				
Total Catch				
gr/DSCF	0.005	0.005	0.004	0.005
gr/ACF	0.004	0.004	0.004	0.004
lb/hr	0.17	0.18	0.14	0.16
lb/ton				

TABLE 52

FACILITY 62

Summary of Visible Emission.

Date: 9/28/76

Type of Plant: Feldspar

Type of Discharge: Outlet Stack

Location of Discharge: No.2 Mill Baghouse

Height of Point of Discharge: 100'

Description of Background: trees on hillside

Description of Sky: Overcast

Wind Direction: NW

Color of Plume: No visible plume

Duration of Observation: 2-1/4 hours

Distance from Observer to Discharge Point:
Approx. 40'

Height of Observation Point.
Approx. 100'

Direction of Observer from Discharge Point: E

Wind Velocity: 0-10 mi/hr

Detached Plume: N/A

SUMMARY OF AVERAGE OPACITY

Set Number	Time		Opacity	
	Start	End	Sum	Average
1	09:48	09:54	N	N
2	09:54	10:00	N	N
3	10:00	10:06	N	N
4	10:06	10:12	N	N
5	10:12	10:18	N	N
6	10:18	10:24	N	N
7	10:24	10:30	N	N
8	10:30	10:36	N	N
9	10:36	10:42	N	N
10	10:42	10:48	N	N
11	10:48	10:54	N	N
12	10:54	11:00	N	N
13	11:00	11:06	N	N
14	11:06	11:12	N	N
15	11:12	11:18	N	N
16	11:18	11:24	N	N
17	11:24	11:30	N	N
18	11:30	11:36	N	N
19	11:36	11:42	N	N
20	11:42	11:48	N	N
21	11:48	11:54	N	N
22	11:54	12:00	N	N
23	12:00	12:06	N	N
24				
25				
26				
27				
28				
29				
30				
31				
32				
33				
34				
35				
36				
37				
38				
39				
40				

Sketch Showing How Opacity Varied With Time:

TABLE 53

FACILITY G2

Summary of Visible Emissions

Date: 9/29/76

Type of Plant: Feldspar

Type of Discharge: Outlet Stack

Location of Discharge: No.2 Mill Baghouse

Height of Point of Discharge: 100'

Description of Background: hillside with trees

Description of Sky: Cloudy

Wind Direction: NE

Color of Plume: No visible plume

Duration of Observation: 2 hrs.

Distance from Observer to Discharge Point: approx. 50'

Height of Observation Point: same level as discharge

Direction of Observer from Discharge Point:

Wind Velocity: 0-5 mi/hr

Detached Plume: N/A

SUMMARY OF AVERAGE OPACITY

Set Number	Time Start	Time End	Opacity Sum	Opacity Average
1	08:35	08:40	N	N
2	08:41	08:46	N	N
3	08:47	08:52	N	N
4	08:53	08:58	N	N
5	08:59	09:04	N	N
6	09:05	09:10	N	N
7	09:11	09:16	N	N
8	09:17	09:22	N	N
9	09:23	09:28	N	N
10	09:29	09:34	N	N
11	09:35	09:40	N	N
12	09:41	09:46	N	N
13	09:47	09:52	N	N
14	09:53	09:58	N	N
15	09:59	10:04	N	N
16	10:05	10:10	N	N
17	10:11	10:16	N	N
18	10:17	10:22	N	N
19	10:23	10:28	N	N
20	10:29	10:34	N	N

SUMMARY OF AVERAGE OPACITY

Set Number	Time Start	Time End	Opacity Sum	Opacity Average
21	10:35	10:37	N	N
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
32				
33				
34				
35				
36				
37				
38				
39				
40				

Sketch Showing How Opacity Varied With Time:

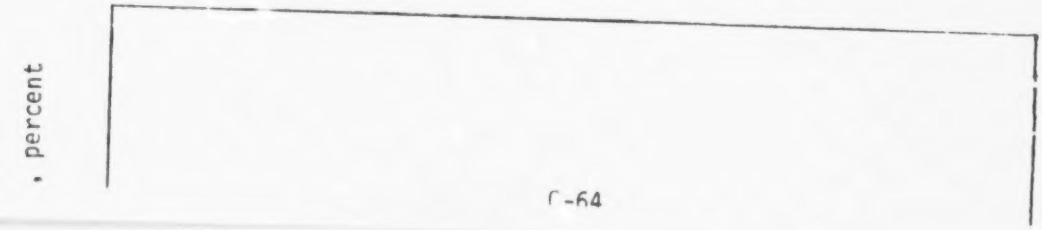


TABLE 54

FACILITY G2

Summary of Visible Emissions

Date: 9/28/76

Type of Plant: Feldspar

Type of Discharge: Outlet Stack

Location of Discharge: No.2 Mill Baghouse

Height of Point of Discharge: 100'

Description of Background: grassy hillside

Description of Sky: partly cloudy

Wind Direction: NW

Color of Plume: No visible plume

Duration of Observation: approx. 2-1/4 hrs.

Distance from Observer to Discharge Point: Approx. 40' SE

Height of Observation Point: Approx. 100'

Direction of Observer from Discharge Point: SE

Wind Velocity: 0-15 mi/hr

Detached Plume: N/A

SUMMARY OF AVERAGE OPACITY

Set Number	Time		Opacity	
	Start	End	Sum	Average
1	14:48	14:54	N	N
2	14:54	15:00	N	N
3	15:00	15:06	N	N
4	15:06	15:12	N	N
5	15:12	15:18	N	N
6	15:18	15:24	N	N
7	15:24	15:30	N	N
8	15:30	15:36	N	N
9	15:36	15:42	N	N
10	15:42	15:48	N	N
11	15:48	15:54	N	N
12	15:54	16:00	N	N
13	16:00	16:06	N	N
14	16:06	16:12	N	N
15	16:12	16:18	N	N
16	16:18	16:24	N	N
17	16:24	16:30	N	N
18	16:30	16:36	N	N
19	16:36	16:42	N	N
20	16:42	16:43	N	N

SUMMARY OF AVERAGE OPACITY

Set Number	Time		Opacity	
	Start	End	Sum	Average
21	16:48	16:54	N	N
22	16:54	17:00	N	N
23				
24				
25				
26				
27				
28				
29				
30				
31				
32				
33				
34				
35				
36				
37				
38				
39				
40				

Sketch Showing How Opacity Varied With Time:

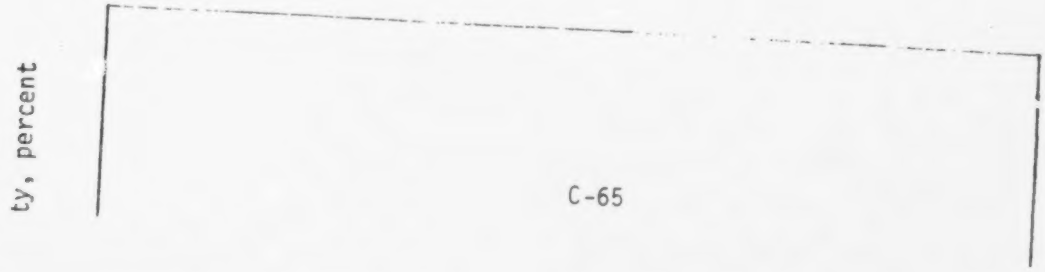


Table 55

FACILITY G2

SUMMARY OF VISIBLE EMISSIONS

Date: 9/28/76

Type of Plant: Feldspar

Type of Discharge: Fugitive

Location of Discharge: Ball mill (feed end)

Height of Point of Discharge: 20 ft.

Description of Background: Building & Equipment

Description of Sky: N/A

Wind Direction: N/A

Color of Plume: No visible plume

Duration of Observation: 1 hour

Distance from Observer to Discharge Point: 35 ft.

Height of Observation Point:

Direction of Observer from Discharge Point: N/A

Wind Velocity: N/A

Detached Plume: N/A

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.		Min.	Sec.
5	0	0	55		
10	-	-	60		
15			65		
20			70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Table 56

FACILITY G2

SUMMARY OF VISIBLE EMISSIONS

Date: 9/28/76

Type of Plant: Feldspar

Type of Discharge: Fugitive

Location of Discharge: Ball mill (discharge end)

Height of Point of Discharge: 20 ft.

Distance from Observer to Discharge Point: 35 ft

Description of Background: Building and equipment

Height of Observation Point:

Description of Sky: N/A

Direction of Observer from Discharge Point: N/A

Wind Direction: N/A

Wind Velocity: N/A

Color of Plume: No visible plume

Detached Plume: N/A

Duration of Observation: 1 hour

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.		Min.	Sec.
5	0	0	55		
10	-	-	60		
15			65		
20			70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Table 57

FACILITY G2

SUMMARY OF VISIBLE EMISSIONS

Date: 9/28/76

Type of Plant: Feldspar

Type of Discharge: Fugitive

Location of Discharge: Indoor transfer point (#1)

Height of Point of Discharge:

Distance from Observer to Discharge Point:

Description of Background: Building wall

Height of Observation Point:

Description of Sky: N/A

Direction of Observer from Discharge Point: N/A

Wind Direction: N/A

Wind Velocity: N/A

Color of Plume: No visible plume

Detached Plume: N/A

Duration of Observation: 1 hour

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity Min.	Sec.
5	0	0
10	-	-
15		
20		
25		
30		
35		
40		
45		
50		
55		
60		
65		
70		
75		
80		
85		
90		
95		
100		

Table 58

FACILITY G2

SUMMARY OF VISIBLE EMISSIONS

Date: 9/28/76

Type of Plant: Feldspar

Type of Discharge: Fugitive

Location of Discharge: Indoor transfer point (#2)

Height of Point of Discharge:

Description of Background: Building wall

Description of Sky: N/A

Wind Direction: N/A

Color of Plume: No visible plume

Duration of Observation: 1 hour

Distance from Observer to Discharge Point:

Height of Observation Point:

Direction of Observer from Discharge Point: N/A

Wind Velocity: N/A

Detached Plume: N/A

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.
5	0	0
10	-	-
15		
20		
25		
30		
35		
40		
45		
50		
55		
60		
65		
70		
75		
80		
85		
90		
95		
100		

Reproduced from best available copy.

Table 59

FACILITY G2

SUMMARY OF VISIBLE EMISSIONS

Date: 9/28/76

Type of Plant: Feldspar

Type of Discharge: Fugitive

Location of Discharge: Indoor Bucket Elevator

Height of Point of Discharge:

Distance from Observer to Discharge Point:

Description of Background: Building walls

Height of Observation Point:

Description of Sky: N/A

Direction of Observer from Discharge Point: N/A

Wind Direction: N/A

Wind Velocity: N/A

Color of Plume: No visible plume

Detached Plume: N/A

Duration of Observation: 1 hour

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacit	
	Min.	Sec.		Min.	Sec.
5	0	0	55		
10	-	-	60		
15			65		
20			70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Table 60

FACILITY G2

SUMMARY OF VISIBLE EMISSIONS

Date: 9/28/76

Type of Plant: Feldspar

Type of Discharge: Fugitive

Location of Discharge: Truck loading

Height of Point of Discharge: 15 ft.

Description of Background: Building wall

Description of Sky: N/A

Wind Direction: N/A

Color of Plume: N/A

Duration of Observation: 13 minutes

Distance from Observer to Discharge Point: 30 ft.

Height of Observation Point: ground level

Direction of Observer from Discharge Point: E

Wind Velocity: N/A

Detached Plume: N/A

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity Min.	Sec.	Opacity, Percent	Total Time Equal to or Greater Than Given Opacity Min.	Sec.
5	0	0	55		
10	-	-	60		
15			65		
20			70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Table 61

FACILITY G2

SUMMARY OF VISIBLE EMISSIONS

Date: 9/28/76

Type of Plant: Feldspar

Type of Discharge: Fugitive

Location of Discharge: Railroad car loading

Height of Point of Discharge: 15 ft.	Distance from Observer to Discharge Point: 25 ft.
Description of Background: Building wall	Height of Observation Point: ground level
Description of Sky: Cloudy	Direction of Observer from Discharge Point: E
Wind Direction: N/A	Wind Velocity: N/A
Color of Plume: N/A	Detached Plume: N/A

Duration of Observation: 32 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity Min.	Sec.	Opacity, Percent	Total Time Equal to or Greater Than Given Opacity Min.	Sec.
5	5	15	55		
10	0	0	60		
15	-	-	65		
20			70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Table 62

FACILITY H1

SUMMARY OF VISIBLE EMISSIONS

Date: 10/27 - 28/76

Type of Plant: Gypsum

Type of Discharge: Fugitive (leaks)

Location of Discharge: Hammermill

Height of Point of Discharge: Leaks

Distance from Observer to Discharge Point: 25 ft.

Description of Background: Inside plant

Height of Observation Point: ground level

Description of Sky: N/A

Direction of Observer from Discharge Point: SW

Wind Direction: N/A

Wind Velocity: N/A

Color of Plume: White

Detached Plume: N/A

Duration of Observation: 298 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.		Min.	Sec.
5	1	45	55		
10	0	15	60		
15	0	0	65		
20	-	-	70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Reproduced from best available copy.

Table 63
FACILITY H2

Summary of Results

Run Number	1	2	3	Average
Date	10/27/76	10/27/76	10/28/76	
Test Time-minutes	88	88	88	88
Production rate - TPH	-	-	-	-
Stack Effluent				
Flow rate - ACFM	4,548	4,364	4,306	4,406
Flow rate - DSCFM	3,542	3,486	3,423	3,484
Temperature - °F	145.4	147.0	145.3	145.9
Water vapor - Vol.%	4.6	1.8	2.6	3.0
Visible Emissions at Collector Discharge - Percent Opacity	See Table 64			
Particulate Emissions				
Probe and Filter Catch				
gr/DSCF	0.071	0.063	0.066	0.067
gr/ACF	0.055	0.050	0.053	0.053
lb/hr	2.16	1.87	1.94	1.99
lb/ton	-	-	-	-
Total Catch				
gr/DSCF	0.073	0.064	0.068	0.068
gr/ACF	0.057	0.051	0.054	0.054
lb/hr	2.53	2.40	2.65	2.53
lb/ton	-	-	-	-

TABLE 64

FACILITY H2

Summary of Visible Emissions

Date: 10/27/76

Type of Plant: Gypsum board manufacturer

Type of Discharge: Stack

Distance from Observer to Discharge Point: 25 ft.

Location of Discharge: Above plant roof

Height of Observation Point: roof level

Height of Point of Discharge: 6' above roof

Direction of Observer from Discharge Point: 225° (S.W.)

Description of Background: Sky

Description of Sky: Clear

Wind Direction: 0° (N)

Wind Velocity: ~ 10 mph

Color of Plume: White

Detached Plume: No

Duration of Observation: 87 Min

SUMMARY OF AVERAGE OPACITY					SUMMARY OF AVERAGE OPACITY				
	Time		Opacity			Time		Opacity	
Set Number	Start	End	Sum	Average	Set Number	Start	End	Sum	Average
1	1312:00	1316:45	125	6.25	21				
2	1357:00	1402:45	155	6.46	22				
3	1403:00	1408:45	135	5.62	23				
4	1409:00	1414:45	150	6.25	24				
5	1415:00	1420:45	140	5.83	25				
6	1421:00	1426:45	125	5.21	26				
7	1427:00	1432:45	135	5.62	27				
8	1433:00	1438:45	130	5.42	28				
9	1439:00	1444:45	125	5.21	29				
10	1445:00	1450:45	115	4.79	30				
11	1451:00	1456:45	95	3.96	31				
12	1457:00	1502:45	70	2.92	32				
13	1503:00	1508:45	80	3.33	33				
14	1509:00	1514:45	85	3.54	34				
15	1515:00	1519:05	60	3.53	35				
16					36				
17					37				
18					38				
19					39				
20					40				

Sketch Showing How Opacity Varied With Time:

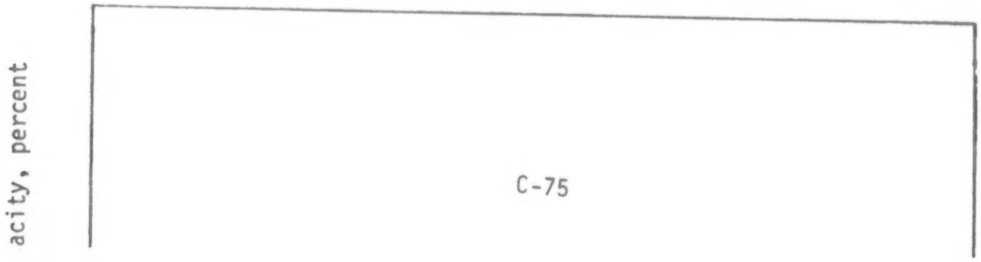


TABLE 64 (con't)

FACILITY H2

Summary of Visible Emissions

Date: 10/27/76

Type of Plant: Gypsum board manufacturer

Type of Discharge: Stack

Location of Discharge: Above plant roof

Height of Point of Discharge: 6' above roof

Description of Background: Sky

Description of Sky: Clear

Wind Direction: 45° (N.E.)

Color of Plume: White

Duration of Observation: 92 min.

Distance from Observer to Discharge Point: 25 ft.

Height of Observation Point: roof level

Direction of Observer from Discharge Point: 225° (S.W.)

Wind Velocity: ~ 10-15 mph

Detached Plume: No

SUMMARY OF AVERAGE OPACITY

	Time		Opacity			Time		Opacity	
Set Number	Start	End	Sum	Average	Set Number	Start	End	Sum	Average
1	0830:00	0835:45	45	1.87	21				
2	0836:00	0841:45	65	2.71	22				
3	0842:00	0847:45	70	2.92	23				
4	0848:00	0849:00	5	1.00	24				
5	0957:00	1002:45	125	5.21	25				
6	1003:00	1008:45	60	2.50	26				
7	1009:00	1014:45	80	3.33	27				
8	1015:00	1020:45	85	3.54	28				
9	1021:00	1026:45	75	3.12	29				
10	1027:00	1032:45	70	2.92	30				
11	1033:00	1038:45	85	3.54	31				
12	1039:00	1044:45	95	3.96	32				
13	1045:00	1050:45	90	3.75	33				
14	1051:00	1056:45	90	3.75	34				
15	1057:00	1102:45	70	2.92	35				
16	1103:00	1108:45	55	2.29	36				
17	1109:00	1110:45	25	3.12	37				
18					38				
19					39				
20					40				

Sketch Showing How Opacity Varied With Time:

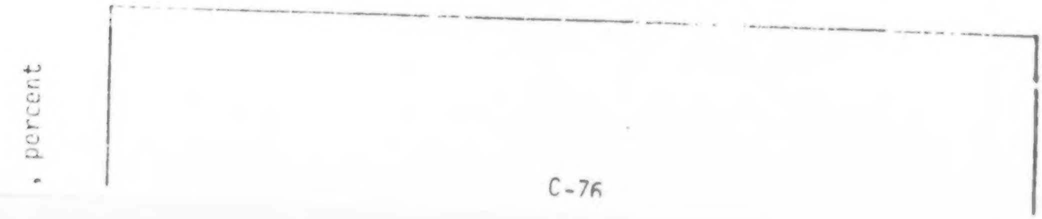


TABLE 64 (con't)
FACILITY H2
Summary of Visible Emissions

Date: 10/28/76

Type of Plant: Gypsum board manufacturer

Type of Discharge: Stack

Distance from Observer to Discharge Point: 25 ft

Location of Discharge: Above plant roof

Height of Observation Point: roof level

Height of Point of Discharge: 6' above roof

Direction of Observer from Discharge Point: 225° (S.W.)

Description of Background: Sky

Description of Sky: Clear

Wind Direction: 180° (S)

Wind Velocity: ~ 10 mph

Color of Plume: White

Detached Plume: No

Duration of Observation: 87 min

SUMMARY OF AVERAGE OPACITY — SUMMARY OF AVERAGE OPACITY

	Time		Opacity			Time		Opacity	
Set Number	Start	End	Sum	Average	Set Number	Start	End	Sum	Average
1	0830:00	0835:45	40	1.67	21				
2	0930:00	0935:45	95	3.96	22				
3	0936:00	0941:45	85	3.54	23				
4	0942:00	0947:45	65	2.71	24				
5	0948:00	0953:45	70	2.92	25				
6	0945:00	0959:45	60	2.50	26				
7	1000:00	1005:45	90	3.75	27				
8	1006:00	1011:45	40	2.50	28				
9	1012:00	1017:45	30	1.25	29				
10	1018:00	1023:45	25	1.04	30				
11	1024:00	1029:45	40	1.67	31				
12	1030:00	1035:45	60	2.50	32				
13	1036:00	1041:45	25	1.04	33				
14	1042:00	1047:45	70	2.92	34				
15	1048:00	1050:45	10	0.83	35				
16					36				
17					37				
18					38				
19					39				
20					40				

Sketch Showing How Opacity Varied With Time:

Table 65

FACILITY I

SUMMARY OF VISIBLE EMISSIONS

Date: 9/30/76

Type of Plant: Mica

Type of Discharge: Fugitive

Location of Discharge: Bagging Operation

Height of Point of Discharge: 3 ft.

Distance from Observer to Discharge Point: 7 ft.

Description of Background: Indoors

Height of Observation Point: ground level

Description of Sky: N/A

Direction of Observer from Discharge Point: N/A

Wind Direction: N/A

Wind Velocity: N/A

Color of Plume: N/A.

Detached Plume: N/A

Duration of Observation: 1 hour

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.		Min.	Sec.
5	0	0	55		
10	-	-	60		
15			65		
20			70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Table 66

FACILITY J1

SUMMARY OF VISIBLE EMISSIONS

Date: 10/20 - 21/76

Type of Plant: Talc

Type of Discharge: Fugitive (leaks)

Location of Discharge: Vertical mill

Height of Point of Discharge: In room

Distance from Observer to Discharge Point: 10 ft.

Description of Background: ceiling

Height of Observation Point: Floor

Description of Sky: N/A

Direction of Observer from Discharge Point: W

Wind Direction: N/A

Wind Velocity: N/A

Color of Plume: White

Detached Plume: N/A

Duration of Observation: 90 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.		Min.	Sec.
5	0	0	55		
10	-	-	60		
15			65		
20			70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Table 67

FACILITY J1

SUMMARY OF VISIBLE EMISSIONS

Date: 10/20/76

Type of Plant: Talc

Type of Discharge: Fugitive

Location of Discharge: Primary crusher

Height of Point of Discharge: In room

Distance from Observer to Discharge Point: 5 ft

Description of Background: wall

Height of Observation Point: Floor

Description of Sky: N/A

Direction of Observer from Discharge Point: W

Wind Direction: N/A

Wind Velocity: N/A

Color of Plume: White

Detached Plume: N/A

Duration of Observation: 90 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.		Min.	Sec.
5	20	15	55		
10	8	0	60		
15	1	15	65		
20	0	0	70		
25	--	--	75		
30			80		
35			85		
40			90		
45			95		
50			100		

Table 68

FACILITY J1

SUMMARY OF VISIBLE EMISSIONS

Date: 10/20 - 21/76

Type of Plant: Talc

Type of Discharge: Fugitive

Location of Discharge: Secondary crusher

Height of Point of Discharge: In room

Distance from Observer to Discharge Point: 5 ft.

Description of Background: wall

Height of Observation Point: floor

Description of Sky: N/A

Direction of Observer from Discharge Point: S

Wind Direction: N/A

Wind Velocity: N/A

Color of Plume: White

Detached Plume: N/A

Duration of Observation: 150 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.		Min.	Sec.
5	3	45	55		
10	0	15	60		
15	0	0	65		
20	-	-	70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Table 69

FACILITY J1

SUMMARY OF VISIBLE EMISSIONS

Date: 10/19 - 21/76

Type of Plant: Talc

Type of Discharge: Fugitive

Location of Discharge: Bagger

Height of Point of Discharge: In room

Distance from Observer to Discharge Point: 10 ft.

Description of Background: wall

Height of Observation Point: floor

Description of Sky: N/A

Direction of Observer from Discharge Point: W

Wind Direction: N/A

Wind Velocity: N/A

Color of Plume: White

Detached Plume: N/A

Duration of Observation: 150 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.		Min.	Sec.
5	12	45	55	0	45
10	5	15	60	0	45
15	3	0	65	0	15
20	2	15	70	0	15
25	2	0	75	0	0
30	2	0	80	-	-
35	1	30	85		
40	1	30	90		
45	1	15	95		
50	1	15	100		

Table 70

FACILITY J1

SUMMARY OF VISIBLE EMISSIONS

Date: 10/19/76

Type of Plant: Talc

Type of Discharge: Fugitive

Location of Discharge: Pebble Mill No. 2

Height of Point of Discharge: In room

Distance from Observer to Discharge Point: 10 ft.

Description of Background: wall

Height of Observation Point: floor

Description of Sky: N/A

Direction of Observer from Discharge Point: W

Wind Direction: N/A

Wind Velocity: N/A

Color of Plume: White

Detached Plume: N/A

Duration of Observation: 90 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.		Min.	Sec.
5	5	0	55		
10	0	45	60		
15	0	0	65		
20	-	-	70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Table 71
FACILITY J2

Summary of Results

Run Number	1	2	3	Average
Date	10/20/76	10/20/76	10/21/76	
Test Time-minutes	120	120	120	120
Production rate - TPH	-	-	-	-
Stack Effluent				
Flow rate - ACFM	21,100	21,300	21,300	21,200
Flow rate - DSCFM	20,200	20,200	19,500	20,000
Temperature - °F	80	83	82	82
Water vapor - Vol.%	0.3	0.3	1.0	0.5
Visible Emissions at Collector Discharge - Percent Opacity	See Table 72			
Particulate Emissions				
Probe and Filter Catch				
gr/DSCF	0.047	0.068	0.067	0.061
gr/ACF	0.045	0.065	0.061	0.057
lb/hr	8.17	11.8	11.2	10.4
lb/ton	-	-	-	-
Total Catch				
gr/DSCF	0.065	0.071	0.068	0.068
gr/ACF	0.062	0.067	0.062	0.064
lb/hr	11.2	12.2	11.3	11.6
lb/ton	-	-	-	-

TABLE 72

FACILITY J2

Summary of Visible Emissions

Date: 10/21/76

Type of Plant: Talc

Type of Discharge: Stack

Location of Discharge: Baghouse Outlet

Height of Point of Discharge: 30'

Description of Background: Hills and trees

Description of Sky: Overcast - rain

Wind Direction: 60° NE

Color of Plume: White

Duration of Observation: Approx. 2 hrs.

Distance from Observer to Discharge Point: approx. 100'

Height of Observation Point: approx. 36'

Direction of Observer from Discharge Point: 160° SE

Wind Velocity: 8-12 mi/hr - Gust up to 20

Detached Plume: N/A

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
1	08:00	08:06	10	0.4
2	08:06	08:12	0	0
3	08:12	08:18	0	0
4	08:18	08:24	5	0.2
5	08:24	08:30	0	0
6	08:30	08:36	5	0.2
7	08:36	08:42	5	0.2
8	08:42	08:48	0	0
9	08:48	08:54	0	0
10	08:54	09:00	0	0
11	09:00	09:06	5	0.2
12	09:06	09:12	10	0.4
13	09:12	09:18	15	0.6
14	09:18	09:24	5	0.2
15	09:24	09:30	5	0.2
16	09:30	09:36	5	0.2
17	09:36	09:42	5	0.2
18	09:42	09:48	0	0
19	09:48	09:54	5	0.2
20	09:54	10:00	5	0.2
21	10:00	10:05	0	0
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
32				
33				
34				
35				
36				
37				
38				
39				
40				

Sketch Showing How Opacity Varied With Time:

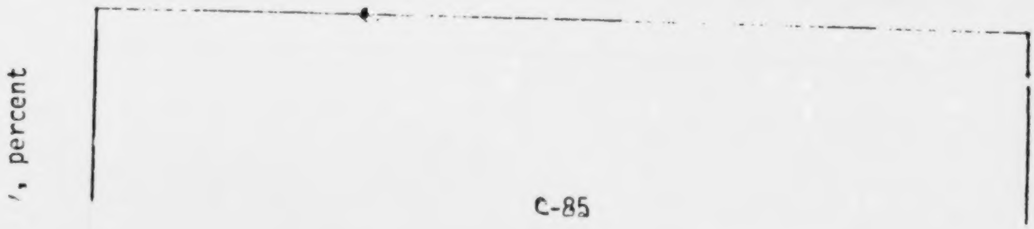


TABLE 72 (con't)

FACILITY J2

Summary of Visible Emissions

Date: 10/20/76

Type of Plant: Talc

Type of Discharge: Stack

Location of Discharge: Baghouse Outlet

Height of Point of Discharge: 30'

Description of Background: Hills and trees

Description of Sky: Overcast - Rain

Wind Direction: 290° NW

Color of Plume: White

Duration of Observation: 2:05 min.

Distance from Observer to Discharge Point: 100'

Height of Observation Point: approx. 36'

Direction of Observer from Discharge Point: 160° SE

Wind Velocity: 4-7 mi/hr

Detached Plume: N/A

SUMMARY OF AVERAGE OPACITY

	Time		Opacity			Time		Opacity	
Set Number	Start	End.	Sum	Average	Set Number	Start	End	Sum	Average
1	12:54	13:00	0	0	21	14:54	14:59	0	0
2	13:00	13:06	0	0	22				
3	13:06	13:12	0	0	23				
4	13:12	13:18	5	0.2	24				
5	13:18	13:24	5	0.2	25				
6	13:24	13:30	10	0.4	26				
7	13:30	13:36	5	0.2	27				
8	13:36	13:42	5	0.2	28				
9	13:42	13:48	15	0.6	29				
10	13:48	13:54	15	0.6	30				
11	13:54	14:00	5	0.2	31				
12	14:00	14:06	0	0	32				
13	14:06	14:12	5	0.2	33				
14	14:12	14:18	0	0	34				
15	14:18	14:24	5	0.2	35				
16	14:24	14:30	0	0	36				
17	14:30	14:36	5	0.2	37				
18	14:36	14:42	5	0.2	38				
19	14:42	14:48	0	0	39				
20	14:48	14:54	0	0	40				

Sketch Showing How Opacity Varied With Time:

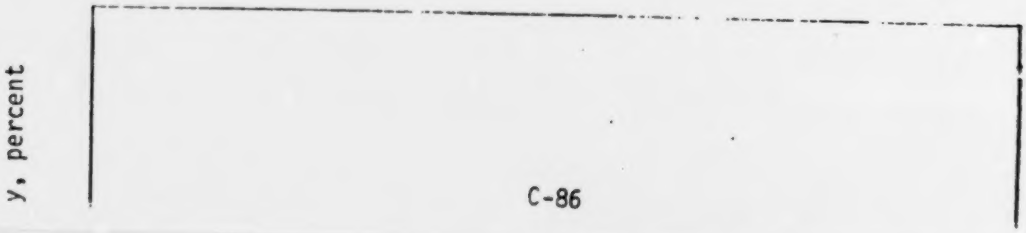


TABLE 72 (con't)

FACILITY J2

Summary of Visible Emissions

Date: 10/20/76

Type of Plant: Talc

Type of Discharge: Stack

Location of Discharge: Baghouse Outlet

Height of Point of Discharge: 30'

Description of Background: Hills and trees

Description of Sky: Overcast

Wind Direction: 290° NW

Color of Plume: White

Duration of Observation: 2:22 min.

Distance from Observer to Discharge Point: approx. 100'

Height of Observation Point: approx. 36'

Direction of Observer from Discharge Point: 160° SE

Wind Velocity: 4-7 mi/hr

Detached Plume: N/A

SUMMARY OF AVERAGE OPACITY

Set Number	Time Start	Time End	Opacity Sum	Opacity Average
1	08:35	08:41	0	0
2	08:41	08:47	5	0.2
3	08:47	08:53	5	0.2
4	08:53	08:59	5	0.2
5	08:49	09:05	5	0.2
6	09:05	09:11	5	0.2
7	09:11	09:17	10	0.4
8	09:17	09:23	5	0.2
9	09:23	09:29	5	0.2
10	09:29	09:35	5	0.2
11	09:35	09:41	0	0
12	09:41	09:47	10	0.4
13	09:47	09:53	0	0
14	09:53	09:59	0	0
15	09:59	10:05	5	0.2
16	10:05	10:11	5	0.2
17	10:11	10:17	10	0.4
18	10:17	10:23	5	0.2
19	10:23	10:29	0	0
20	10:29	10:35	10	0.4

SUMMARY OF AVERAGE OPACITY

Set Number	Time Start	Time End	Opacity Sum	Opacity Average
21	10:35	10:41	5	0.2
22	10:41	10:47	5	0.2
23	10:47	10:53	10	0.4
24	10:53	10:58	5	0.25
25				
26				
27				
28				
29				
30				
31				
32				
33				
34				
35				
36				
37				
38				
39				
40				

Sketch Showing How Opacity Varied With Time:

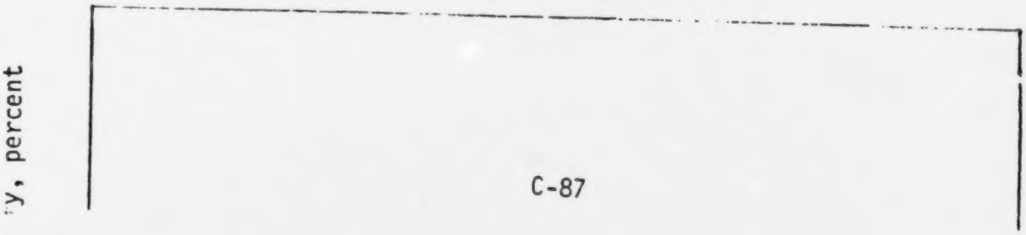


Table 73
FACILITY K

Summary of Results

Run Number	1	2	3	Average
Date	6/21/77	6/21/77	6/22/77	
Test Time-minutes	120	120	120	120
Production rate - TPH	-	-	-	-
Stack Effluent				
Flow rate - ACFM	4,567	4,113	4,579	4,420
Flow rate - DSCFM	3,637	3,196	3,646	3,493
Temperature - °F	135.3	152.3	136.8	141.5
Water vapor - Vol.%	1.69	1.36	1.63	1.56
Visible Emissions at Collector Discharge - Percent Opacity	See Table 74			
Particulate Emissions				
Probe and Filter Catch				
gr/DSCF	0.024	0.027	0.041	0.031
gr/ACF	0.020	0.022	0.034	0.025
lb/hr	0.75	0.75	1.29	0.93
lb/ton	-	-	-	-
Total Catch				
gr/DSCF				
gr/ACF				
lb/hr				
lb/ton				

TABLE 74

FACILITY K

Summary of Visible Emissions

Date: 6/20 - 6/21/71

Type of Plant: Talc

Type of Discharge: Stack

Distance from Observer to Discharge Point: 125 ft.

Location of Discharge: Pebble mill

Height of Observation Point: 25 ft.

Height of Point of Discharge: 40 ft.

Direction of Observer from Discharge Point: W

Description of Background: Equipment and Mountain

Description of Sky: Clear

Wind Direction: North

Wind Velocity: 5 mph

Color of Plume: White

Detached Plume: N/A

Duration of Observation:

SUMMARY OF AVERAGE OPACITY | SUMMARY OF AVERAGE OPACITY

	Time		Opacity			Time		Opacity	
Set Number	Start	End	Sum	Average	Set Number	Start	End	Sum	Average
1	1314	1320	80	3.33	21	802	808	10	0.42
2	1320	1326	10	0.42	22	808	814	5	0.21
3	1326	1332	5	0.21	23	814	820	5	0.21
4	1332	1338	10	0.42	24	820	826	30	1.25
5	1338	1344	10	0.42	25	826	832	0	0.0
6	1344	1350	0	0.0	26	832	838	0	0.0
7	1350	1356	5	0.21	27	838	844	40	1.67
8	1356	1402	0	0.0	28	844	850	75	3.13
9	1402	1408	5	0.21	29	850	856	50	2.08
10	1408	1414	5	0.21	30	856	902	65	2.32
11	1417	1423	5	0.21	31	903	909	35	1.46
12	1423	1429	5	0.21	32	909	915	20	0.83
13	1429	1435	5	0.21	33	915	921	55	2.29
14	1435	1441	10	0.42	34	921	927	25	1.04
15	1441	1447	5	0.21	35	927	933	55	2.29
16	1447	1453	0	0.0	36	933	939	55	2.29
17	1453	1459	0	0.0	37	939	945	30	1.24
18	1459	1505	5	0.21	38	945	951	55	2.29
19	1505	1511	0	0.0	39	951	957	70	2.92
20	1511	1517	10	0.42	40	957	1003	40	1.67

Sketch Showing How Opacity Varied With Time:

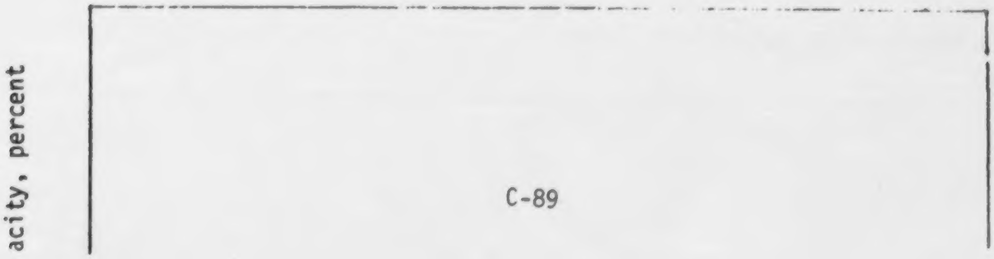


TABLE 74 (con't)

FACILITY K

Summary of Visible Emissions

Date: 6/20 - 6/21/71

Type of Plant: Talc

Type of Discharge: Stack

Distance from Observer to Discharge Point: 125 ft.

Location of Discharge: Pebble Mill

Height of Observation Point: 25 ft.

Height of Point of Discharge: 40 ft.

Direction of Observer from Discharge Point: W

Description of Background: Equipment and Mountain

Description of Sky: Clear

Wind Direction: North

Wind Velocity: 5 mph

Color of Plume: White

Detached Plume: N/A

Duration of Observation:

SUMMARY OF AVERAGE OPACITY

	Time		Opacity			Time		Opacity	
Set Number	Start	End	Sum	Average	Set Number	Start	End	Sum	Average
1	1004	1009	30	1.25	21	1407	1413	125	5.21
2	1208	1214	105	4.38	22				
3	1214	1220	110	4.58	23				
4	1220	1226	85	3.54	24				
5	1226	1232	90	3.75	25				
6	1232	1238	125	5.21	26				
7	1238	1244	85	3.54	27				
8	1244	1250	105	4.38	28				
9	1250	1256	95	3.96	29				
10	1256	1302	25	1.32	30				
11	1302	1308	65	2.95	31				
12	1313	1319	95	3.96	32				
13	1319	1325	105	4.38	33				
14	1325	1331	40	1.67	34				
15	1331	1337	30	1.30	35				
16	1337	1343	60	2.61	36				
17	1343	1349	55	2.29	37				
18	1349	1355	35	1.94	38				
19	1355	1401	5	0.36	39				
20	1401	1407	75	3.13	40				

Sketch Showing How Opacity Varied With Time:

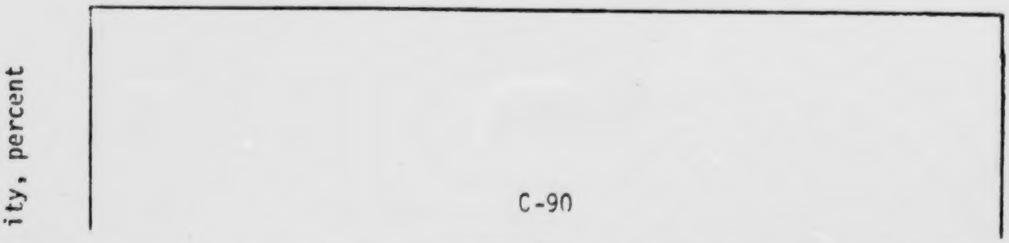


TABLE 75

FACILITY L1

Summary of Results

Run Number	1*
Date	12/6/78
Test Time - Minutes	60
Production Rate - TPH	-
Stack Effluent	
Flow rate - ACFM	17180
Flow rate- DSCFM	14040
Temperature - °F	136
Water vapor - Vol. %	7.4
Visible Emissions at Collector Discharge - % Opacity	-
Particulate Emissions	
Probe and Filter catch	
gr/DSCF	4.53
gr/ACF	3.70
lb/hr	545
lb/ton	-
Total catch (1)	
gr/DSCF	
gr/ACF	
lb/hr	
lb/ton	

* Test conducted concurrently with Run 2, Table 76.

(1) No analysis of back-half on in-stack filter tests.

TABLE 76

FACILITY L1

Summary of Results

Run Number	1	2*	3	Average
Date	12/6/78	12/6/78	12/6/68	-
Test Time - Minutes	96	96	96	96
Production Rate - TPH	-	-	-	-
Stack Effluent				
Flow rate - ACFM	17690	17960	18060	17903
Flow rate- DSCFM	14790	14650	15080	14840
Temperature - ^{o}F	131.	141.	141.	138
Water vapor - Vol. %	7.0	7.8	5.4	6.7
Visible Emissions at Collector Discharge - % Opacity	see Table 77	-	-	-
Particulate Emissions				
Probe and Filter catch				
gr/DSCF	0.020	0.012	0.016	0.016
gr/ACF	0.017	0.010	0.013	0.013
lb/hr	2.49	1.54	2.01	2.01
lb/ton	-	-	-	-
Total catch(1)				
gr/DSCF				
gr/ACF				
lb/hr				
lb/ton				

*Test conducted concurrently with Run 1, Table 75.

(1) No analysis of back-half on in-stack filter tests.

TABLE 77

FACILITY L1

Summary of Visible Emissions

Date: 12/6/78

Type of Plant: Clay Processing

Type of Discharge: Stack

Distance from Observer to Discharge Point: 7 ft.

Location of Discharge: Baghouse

Height of Observation Point: 80 ft.

Height of Point of Discharge: 80 ft.

Direction of Observer from Discharge Point: South

Description of Background: Green Pine Forest

Description of Sky: Blue

Wind Direction: Northwest

Wind Velocity: 5 mi/hr.

Color of Plume: White

Detached Plume: No

Duration of Observation: 90 minutes

SUMMARY OF AVERAGE OPACITY

Set Number	Time Start	Time End	Opacity Sum	Opacity Average
1	1400	1406	0	0
2	1406	1412	0	0
3	1412	1418	0	0
4	1418	1424	0	0
5	1424	1430	0	0
6	1430	1436	0	0
7	1436	1442	0	0
8	1442	1448	0	0
9	1448	1454	0	0
10	1454	1500	0	0
11	1500	1506	0	0
12	1506	1512	0	0
13	1512	1518	0	0
14	1518	1524	0	0
15	1524	1530	0	0

TABLE 78

FACILITY L2

Summary of Results

Run Number	1
Date	12/6/78
Test Time - Minutes	56
Production Rate - TPH	-
Stack Effluent	
Flow rate - ACFM	8550
Flow rate- DSCFM	6960
Temperature - °F	134
Water vapor - Vol. %	7.9
Visible Emissions at Collector Discharge - % Opacity	see Table 82
Particulate Emissions	
Probe and Filter catch	
gr/DSCF	1.76
gr/ACF	1.43
lb/hr	105.
lb/ton	-
Total catch(1)	
gr/DSCF	
gr/ACF	
lb/hr	
lb/ton	

(1) No analysis of back-half on in-stack filter tests.

TABLE 79

FACILITY L2

Summary of Results

Run Number	1	2	3	Average
Date	12/5/78	12/5/78	12/6/78	-
Test Time - Minutes	120	120	120	120
Production Rate - TPH	-	-	-	-
Stack Effluent				
Flow rate - ACFM	9780	9830	10340	9983
Flow rate- DSCFM	8120	8150	8560	8277
Temperature - °F	129	123	136	129
Water vapor - Vol. %	8.4	9.4	6.7	8.2
Visible Emissions at Collector Discharge - % Opacity	see Table 80	see Table 81	see Table 82	-
Particulate Emissions				
Probe and Filter catch				
gr/DSCF	0.010	0.005	0.007	0.007
gr/ACF	0.008	0.004	0.006	0.006
lb/hr	0.73	0.38	0.48	0.53
lb/ton	-	-	-	-
Total catch(1)				
gr/DSCF				
gr/ACF				
lb/hr				
lb/ton				

(1) No analysis of back-half on in-stack filter tests.

TABLE 80

FACILITY L2

Summary of Visible Emissions

Date: 12/5/78

Type of Plant: Clay

Type of Discharge: Stack

Distance from Observer to Discharge Point: 25 ft.

Location of Discharge: Baghouse

Height of Observation Point: 100 ft.

Height of Point of Discharge: 100 Ft.

Direction of Observers from Discharge Point: Southeast

Description of Background: Clear Blue

Description of Sky: Clear Blue

Wind Direction: East

Wind Velocity: 5-10 mi/hr.

Color of Plume: White

Detached Plume: Yes

Duration of Observation: approx. 120 minutes

SUMMARY OF AVERAGE OPACITY

Set Number	Time		Opacity		Set Number	Time		Opacity	
	Start	End	Sum	Average		Start	End	Sum	Average
1	0953:00	0959:15	120	5	21	1202:30	1203:00	10	5
2	0959:15	1005:45	120	5					
3	1005:45	1011:45	120	5					
4	1011:45	1018:15	120	5					
5	1018:15	1024:15	120	5					
6	1024:15	1030:45	120	5					
7	1030:15	1037:00	100	4.2					
8	1037:00	1039:00							
	1044:00	1048:00	80	3.3					
9	1048:00	1054:15	120	5					
10	1054:15	1100:15	120	5					
11	1100:15	1106:15	120	5					
12	1106:15	1112:15	120	5					
13	1112:15	1118:30	120	5					
14	1118:30	1124:30	120	5					
15	1124:30	1131:00	120	5					
16	1131:00	1137:00	120	5					
17	1137:00	1143:15	120	5					
18	1143:15	1149:30	120	5					
19	1149:30	1156:30	115	4.8					
20	1156:30	1202:30	110	4.6					

TABLE 81

FACILITY L2

Summary of Visible Emissions

Date: 12/78

Type of Plant: Clay

Type of Discharge: Stack

Distance from Observer to Discharge Point: 25 ft.

Location of Discharge: Baghouse

Height of Observation Point: 100 ft.

Height of Point of Discharge: 100 ft.

Direction of Observer from Discharge Point: South east

Description of Background: Clear Blue

Description of Sky: Clear Blue

Wind Direction: East

Wind Velocity: 5-10 mi/hr.

Color of Plume: White

Detached Plume: Yes

Duration of Observation: 128 minutes

SUMMARY OF AVERAGE OPACITY

Set	Time		Opacity		Set	Time		Opacity	
Number	Start	End	Sum	Average	Number	Start	End	Sum	Average
1	1357	1403	0	0	21	1557	1603	0	0
2	1403	1409	0	0	22	1603	1605	0	0
3	1409	1415	0	0					
4	1415	1421	0	0					
5	1421	1427	0	0					
6	1427	1433	0	0					
7	1433	1439	0	0					
8	1439	1445	0	0					
9	1445	1451	0	0					
10	1451	1457	0	0					
11	1457	1503	0	0					
12	1503	1509	0	0					
13	1509	1515	0	0					
14	1515	1521	0	0					
15	1521	1527	0	0					
16	1527	1533	0	0					
17	1533	1539	0	0					
18	1539	1545	0	0					
19	1545	1551	0	0					
20	1551	1557	0	0					

TABLE 82

FACILITY L2

Summary of Visible Emissions

Date: 12/5/78

Type of Plant: Clay

Type of Discharge: Stack

Distance from Observer to Discharge Point: 25 ft.

Location of Discharge: Baghouse

Height of Observation Point: 100 ft.

Height of Point of Discharge: 100 ft.

Direction of Observer from Discharge Point: South east

Description of Background: Clear Blue

Description of Sky: Clear Blue

Wind Direction: East

Wind Velocity: 5-10 mi/hr.

Color of Plume: White

Detached Plume: Yes

Duration of Observation: approx. 120 minutes

SUMMARY OF AVERAGE OPACITY

Set Number	Time		Opacity		Set Number	Time		Opacity	
	Start	End	Sum	Average		Start	End	Sum	Average
1	1050	1056	0	0					
2	1056	1102	0	0					
3	1102	1108	0	0					
4	1108	1114	0	0					
5	1114	1120	0	0					
6	1120	1126	0	0					
7	1126	1132	0	0					
8	1132	1138	0	0					
9	1138	1144	0	0					
10	1144	1150	0	0					
11	1152	1158	0	0					
12	1158	1204	0	0					
13	1204	1210	0	0					
14	1210	1216	0	0					
15	1216	1222	0	0					
16	1222	1228	0	0					
17	1228	1234	0	0					
18	1234	1240	0	0					
19	1240	1246	0	0					
20	1246	1251	0	0					

TABLE 83

FACILITY M1

Summary of Results

Run Number	1	2	3	Average
Date	6/14/78	6/15/78	6/15/78	-
Test Time - Minutes	120	120	120	120
Production Rate - TPH	-	-	-	-
Stack Effluent				
Flow rate - ACFM	1840	1490	1560	1630
Flow rate- DSCFM	1620	1300	1360	1427
Temperature - °F	124	121	124	123
Water vapor - Vol. %	2.8	4.1	4.2	3.7
Visible Emissions at Collector Discharge - % Opacity	see Table 84	see Table 85	see Table 86	-
Particulate Emissions				
Probe and Filter catch				
gr/DSCF	0.001	0.001	0.007	0.003
gr/ACF	0.001	0.001	0.006	0.003
lb/hr	0.01	0.02	0.09	0.04
lb/ton	-	-	-	-
Total catch(1)				
gr/DSCF				
gr/ACF				
lb/hr				
lb/ton				

(1) No analysis of back-half on in-stack filter tests.

TABLE 84

FACILITY M1

Summary of Visible Emissions

Date: 6/14/78

Type of Plant: Clay

Type of Discharge: Stack

Distance from Observer to Discharge Point: 90 ft.

Location of Discharge: Baghouse

Height of Observation Point: 35 ft.

Height of Point of Discharge:

Direction of Observer from Discharge Point: East

Description of Background: Sky

Description of Sky: Partly cloudy

Wind Direction: NNE

Wind Velocity: 10 mi/hr.

Color of Plume:

Detached Plume:

Duration of Observation: 151 minutes

SUMMARY OF AVERAGE OPACITY

Set	Time		Opacity		Set	Time		Opacity	
Number	Start	End	Sum	Average	Number	Start	End	Sum	Average
1	1538	1544	0	0	21	1738	1744	0	0
2	1544	1550	0	0	22	1744	1750	0	0
3	1550	1556	0	0	23	1750	1756	0	0
4	1556	1602	0	0	24	1756	1802	0	0
5	1602	1608	0	0	25	1802	1808	0	0
6	1608	1614	0	0	26	1808	1809	0	0
7	1614	1620	0	0	27				
8	1620	1626	0	0	28				
9	1626	1632	0	0	29				
10	1632	1638	0	0	30				
11	1638	1644	0	0	31				
12	1644	1650	0	0	32				
13	1650	1656	0	0	33				
14	1656	1702	0	0	34				
15	1702	1708	0	0	35				
16	1708	1714	0	0	36				
17	1714	1720	0	0	37				
18	1720	1726	0	0	38				
19	1726	1732	0	0	39				
20	1732	1738	0	0	40				

TABLE 85

FACILITY M1

Summary of Visible Emissions

Date: 6/15/78

Type of Plant: Clay

Type of Discharge: Stack

Distance from Observer to Discharge Point: 90 ft.

Location of Discharge: Baghouse

Height of Observation Point: 35 ft.

Height of Point of Discharge:

Direction of Observer from Discharge Point: East

Description of Background: Sky

Description of Sky: cloudy

Wind Direction: NNE

Wind Velocity: 10 mi/hr.

Color of Plume:

Detached Plume:

Duration of Observation: 134 minutes

SUMMARY OF AVERAGE OPACITY

Set Number	Time		Opacity		Set Number	Time		Opacity	
	Start	End	Sum	Average		Start	End	Sum	Average
1	913	919	0	0	21	1113	1119	0	0
2	919	925	0	0	22	1119	1125	0	0
3	925	931	0	0	23	1125	1127	0	0
4	931	937	0	0	24				
5	937	943	0	0	25				
6	943	949	0	0	26				
7	949	955	0	0	27				
8	955	1001	0	0	28				
9	1001	1007	0	0	29				
10	1007	1013	0	0	30				
11	1013	1019	0	0	31				
12	1019	1025	0	0	32				
13	1025	1031	0	0	33				
14	1031	1037	0	0	34				
15	1037	1043	0	0	35				
16	1043	1049	0	0	36				
17	1049	1055	0	0	37				
18	1055	1101	0	0	38				
19	1101	1107	0	0	39				
20	1107	1113	0	0	40				

TABLE 86

FACILITY M1

Summary of Visible Emissions

Date: 6/15/78

Type of Plant: Clay

Type of Discharge: Stack

Distance from Observer to Discharge Point: 90 ft.

Location of Discharge: Baghouse

Height of Observation Point: 35 ft.

Height of Point of Discharge:

Direction of Observers from Discharge Point: East

Description of Background: Sky

Description of Sky: cloudy

Wind Direction: NNE

Wind Velocity: 10 mi/hr.

Color of Plume:

Detached Plume:

Duration of Observation: 183 minutes

SUMMARY OF AVERAGE OPACITY

Set	Time		Opacity		Set	Time		Opacity	
Number	Start	End	Sum	Average	Number	Start	End	Sum	Average
1	1332	1338	0	0	21	1606	1608		
2	1338	1344	0	0		1625	1629	0	0
3	1344	1350	0	0	22	1629	1634	0	0
4	1350	1356	0	0	24				
5	1356	1402	0	0	25				
6	1402	1408	0	0	26				
7	1442	1448	0	0	27				
8	1448	1454	0	0	28				
9	1454	1500	0	0	29				
10	1500	1506	0	0	30				
11	1506	1512	0	0	31				
12	1512	1518	0	0	32				
13	1518	1524	0	0	33				
14	1524	1530	0	0	34				
15	1530	1536	0	0	35				
16	1536	1542	0	0	36				
17	1542	1548	0	0	37				
18	1548	1554	0	0	38				
19	1554	1660	0	0	39				
20	1600	1606	0	0	40				

TABLE 87

FACILITY M2

Summary of Results

Run Number	1	2	3	Average
Date	6/14/78	6/15/78	6/15/78	-
Test Time - Minutes	120	120	120	120
Production Rate - TPH	-	-	-	-
Stack Effluent				
Flow rate - ACFM	2580	2460	2450	2497
Flow rate- DSCFM	2100	2090	2100	2097
Temperature - °F	183	151	150	161
Water vapor - Vol. %	1.1	1.7	1.6	1.5
Visible Emissions at Collector Discharge - % Opacity	see Table 88	see Table 89	see Table 90	-
Particulate Emissions				
Probe and Filter catch				
gr/DSCF	0.002	0.002	0.001	0.002
gr/ACF	0.002	0.002	0.001	0.002
lb/hr	0.03	0.04	0.02	0.03
lb/ton	-	-	-	-
Total catch[1]				
gr/DSCF				
gr/ACF				
lb/hr				
lb/ton				

(1) No analysis of back-half on in-stack filter tests.

TABLE 88

FACILITY M2

Summary of Visible Emissions

Date: 6/14/78

Type of Plant: Clay

Type of Discharge: Stack

Distance from Observer to Discharge Point: 90 ft.

Location of Discharge: Baghouse

Height of Observation Point: 85 ft.

Height of Point of Discharge:

Direction of Observer from Discharge Point: East

Description of Background: Sky

Description of Sky: Partly cloudy

Wind Direction: NNE

Wind Velocity: 10 mi/hr.

Color of Plume:

Detached Plume:

Duration of Observation: 30 minutes

SUMMARY OF AVERAGE OPACITY

Set Number	Time Start	Time End	Opacity Sum	Opacity Average	Set Number	Time Start	Time End	Opacity Sum	Opacity Average
1	1528	1534	0	0	21				
2	1534	1540	0	0	22				
3	1540	1546	0	0	23				
4	1546	1552	0	0	24				
5	1552	1558	0	0	25				
6					26				
7					27				
8					28				
9					29				
10					30				
11					31				
12					32				
13					33				
14					34				
15					35				
16					36				
17					37				
18					38				
19					39				
20					40				

TABLE 89

FACILITY M2

Summary of Visible Emissions

Date: 6/15/78

Type of Plant: Clay

Type of Discharge: Stack

Distance from Observer to Discharge Point: 90 ft.

Location of Discharge: Baghouse

Height of Observation Point: 85 ft.

Height of Point of Discharge:

Direction of Observer from Discharge Point: East

Description of Background: Sky

Description of Sky: cloudy

Wind Direction: NNE

Wind Velocity: 10 mi/hr.

Color of Plume:

Detached Plume:

Duration of Observation: 128 minutes

SUMMARY OF AVERAGE OPACITY

Set Number	Time		Opacity		Set Number	Time		Opacity	
	Start	End	Sum	Average		Start	End	Sum	Average
1	850	856	0	0	21	1050	1056	0	0
2	856	902	0	0	22	1056	1058	0	0
3	902	908	0	0	23				
4	908	914	0	0	24				
5	914	920	0	0	25				
6	920	926	0	0	26				
7	926	932	0	0	27				
8	932	938	0	0	28				
9	938	944	0	0	29				
10	944	950	0	0	30				
11	950	956	0	0	31				
12	956	1002	0	0	32				
13	1002	1008	0	0	33				
14	1008	1014	0	0	34				
15	1014	1020	0	0	35				
16	1020	1026	0	0	36				
17	1026	1032	0	0	37				
18	1032	1038	0	0	38				
19	1038	1044	0	0	39				
20	1044	1050	0	0	40				

TABLE 90

FACILITY M2

Summary of Visible Emissions

Date: 6/15/78

Type of Plant: Clay

Type of Discharge: Stack

Distance from Observer to Discharge Point: 90 ft.

Location of Discharge: Baghouse

Height of Observation Point: 85 ft.

Height of Point of Discharge:

Direction of Observers from Discharge Point: East

Description of Background: Sky

Description of Sky: Partly cloudy

Wind Direction: NNE

Wind Velocity: 10 mi/hr.

Color of Plume:

Detached Plume:

Duration of Observation: 139 minutes

SUMMARY OF AVERAGE OPACITY

Set Number	Time Start	Time End	Opacity Sum	Opacity Average	Set Number	Time Start	Time End	Opacity Sum	Opacity Average
1	1359	1405	0	0	21	1559	1605	0	0
2	1405	1411	0	0	22	1605	1611	0	0
3	1411	1417	0	0	23	1611	1617	0	0
4	1417	1423	0	0	24	1617	1618	0	0
5	1423	1429	0	0	25				
6	1429	1435	0	0	26				
7	1435	1441	0	0	27				
8	1441	1447	0	0	28				
9	1447	1453	0	0	29				
10	1453	1459	0	0	30				
11	1459	1505	0	0	31				
12	1505	1511	0	0	32				
13	1511	1517	0	0	33				
14	1517	1523	0	0	34				
15	1523	1529	0	0	35				
16	1529	1535	0	0	36				
17	1535	1541	0	0	37				
18	1541	1547	0	0	38				
19	1547	1553	0	0	39				
20	1553	1559	0	0	40				

TABLE 91

FACILITY N

Summary of Results of Fugitive Emission Tests performed on three separate rail car loadings

Observation area	Accumulated observation period (min:sec)	Accumulated emission time (min:sec)	% Emission (AET/AOP x 100)
		Test #1	
A	144:32	22:42	15.7
B	144:32	17:30	12.1
C	144:32	0:00	0
		Test #2	
A	99:45	18:50	18.9
B	99:45	2:06	2.1
C	99:45	0.00	0
		Test #3	
A	154:20	63:42	41.3
B	154:20	0:20	0.2
C	154:20	9:21	6.1

1. Designation of observation positions

A. Loading hose

B. West end of shed

C. East end of shed

TABLE 92

SUMMARY OF METHOD 22 RESULTS — FACILITY P

Time period	Observed time (minutes)	Percent of time with visible emissions	
		Observer	
		1	2
Test point 5, Final screens, 10/3/79			
1035-1055	20	0	<1
1105-1125	20	<1	0
1130-1150	20	<1	0
Test point 7, Transfer point, 10/3/79			
1324-1424	60	1	1

TABLE 93

METHOD 9 - 6-MINUTE AVERAGES[a]

FACILITY P

Run	TP-1 Primary Crusher		TP-4 Impact Crusher		TP-6 Cone Crusher	
	Observer		Observer		Observer	
	3	4	3	4	3	4
1	9	13	15	10	4	11
2	7	11	11	7	5	18
3	14	15	11	7	9	22
4	14	17	11	10	11	25
5	13	11	11	10	9	23
6	11	11	10	8	10	17
7	12[b]	11	10	13	9	16
8	7[c]	10	11	13	7	15
9	-	13	13	10	10	15
10	9	10	11	9	8	16
11	11	15			8	15
12	10	18			13	21
13	13	10			7	13
14	8	8			8	13
15	10	10			8	15
16	10	11			1	4
17	8	5			0	2
18					0	1
19					0	1
20					1	4

[a] Values reported in percent opacity.

[b] 4-minute average

[c] 5-minute average

TABLE 94
SUMMARY OF METHOD 22 RESULTS - FACILITY Q

Time period	Observed time (minutes)	Percent of time with visible emissions Observer 1	 2
Test point 2, Initial screens, 10/10/79 - 10/11/79			
1010-1040[a]	30	34	65
0820-0856	30	4	7
Test point 3, Transfer point, 10/10/79			
0851-0921[a]	30	27	31
0931-1001[a]	30	64	67
Test point 5, Secondary screens, 10/8/79			
0848-0918	30	0	0
0940-1010	30	0	0
1015-1045	30	0	0
1057-1127	30	<1	0
Test point 7, Final screens, 10/8/79			
1250-1320	30	0	0
1330-1400	30	0	0
1407-1437	30	0	0
1451-1521	30	0	0

[a] "Red Rock" material. Not processed under representative conditions. Data omitted.

TABLE 95

METHOD 9 - 6-MINUTE AVERAGES[a] FACILITY Q

Run	TP-1 Primary crusher		TP-6 Cone crusher	
	Observer		Observer	
	3	4	3	4
1	11	11	15	12
2	11	14	18	17
3	6	8	18	19
4	12	18	17	19
5	12	17	10	12
6	3	5	15	18
7	2	9	19	19
8	1	4	20	21
9	2	8	23	23
10	1	6	24	23
11	1	6	28	24
12	1	7	26	26
13	2	8	28[b]	28[b]
14	3	12	25	23
15	3	10	28	28
16	3	6	29	26
17	2	6	27[c]	26[c]
18	2	5	27	29
19	1	2	29	34
20	1	3	26	38
21			25[c]	39[c]

[a] Values reported in percent opacity.

[b] 4-minute average.

[c] 5-minute average.

TABLE 96
SUMMARY OF METHOD 22 RESULTS - FACILITY R

Time period	Observed time (minutes)	Percent of time with visible emissions	
		Observer	
		1	2
Test point 1, Initial screens 10/12/79, 10/15/79			
0720-0750	30	2	1
0800-0830	30	1	<1
0840-0910	30	2	1
0920-0941 0722-0732	30	2	4
Test point 3, Transfer point, 10/16/79			
0731-0801	30	6	12
Test point 4, Secondary screens, 10/16/79			
0907-0937	30	5	15
0945-1015	30	1	1
1035-1105	30	42[a]	4[a]
1310-1340	30	5	10
Test point 6, Final screens, 10/15/79			
1020-1050	30	0	0
1055-1125	30	0	0
1130-1200	30	0	0
1303-1333	30	0	0
Test point 7A, Transfer point, 10/15/79			
1610-1640	30	0	0
1646-1716	30	0	0
Test point 7B, Transfer point, 10/16/79			
1415-1445	30	0	0
1455-1525	30	4	4

[a] Data omitted - wind interference.

TABLE 97

METHOD 9 - 6-MINUTE AVERAGES[a]
FACILITY R

Run	TP-2 Primary crusher		TP-5 Cone crusher	
	Observer		Observer	
	3	4	3	4
1	14	13	8	12
2	16	14	9	14
3	16	14	9	17
4	16	9	12	15
5	12	13	13	15
6	9	15	11	15
7	13	14	13	16
8	9	14	12	14
9	13	15	13	16
10	12	13	12	14
11	17	16	12	17
12	9	13	10	17
13	14	11	9	17
14	13	12	7	10
15	15	13	8	15
16	8	9	12	10
17	6	6	13	11
18	7	9	11	11
19	10	11	11	11
20	9	12	12	11

[a] Data reported in percent opacity.

TABLE 98

SUMMARY OF METHOD 22 RESULTS - FACILITY S

Time period	Observed time (minutes)	Percent of time with visible emissions	
		Observer	
		1	2
Test point 2, Initial Screens, 10/24/79			
1516-1546	30	0	0
1558-1628	30	0	0
1100-1130	30	0	0
1302-1332	30	0	0
Test point 4, Secondary screens, 10/22/79, 10/23/79			
1108-1138	30	1	10
1143-1158	15	1	13
0745-0805	15	1	5
0810-1840	30	1	6
0845-0915	30	1	7
Test point 6, Transfer point, 10/23/79, 10/24/79			
1257-1327	30	0	0
1335-1350	15	0	1
1338-1353	15	0	0
1355-1425	30	0	0
1433-1503	30	0	0
Test point 7, Transfer point, 10/25/79			
0750-0820	30	0	0
0826-0856	30	0	0
0915-0945	30	0	0
0955-1025	30	0	0

TABLE 99

METHOD 9 - 6-MINUTE AVERAGES[a]
FACILITY S

Run	TP-1 Primary crusher		TP-3 4-1/2 in. Cone crusher		TP-5 5-1/2 in. Cone crusher	
	Observer		Observer		Observer	
	3	4	3	4	3	4
1	2	1	3	3	0	0
2	1	2	4	4	0	2
3	1	1	4	5	3	5
4	1	0	2	3	5	5
5	1	1	4	3	4	4
6	1	3	6	4	10	9
7	1	2	6	4	11	9
8	<1	1	3	2	14	10
9	0	2	2	2	11	10
10	1	1	5	3	13	10
11	1	1	4	3	11	11
12	0	0	5	5	11	10
13	0	0	3	2	12	15
14	0	1	5	4	8	9
15	2	2	5	3	10	12
16	1	0	4	2	12	12
17	3	2	3	0	9	10
18	3	3	3	2	6	9
19	2	1	3	1	7	11
20	0	1	1	2	5	9

[a] Data reported in percent opacity.

TABLE 100

SUMMARY OF METHOD 22 RESULTS - FACILITY T

Time period	Observed time (minutes)	Percent of time with visible emissions Observer 1	Percent of time with visible emissions Observer 2
Test point 2, Transfer point, 10/26/79, 10/29/79			
1353-1427	30	0	1
1428-1458	30	4	2
1533-1603	30	3	1
1125-1155	30	2	0
Test point 3, Initial screens, 10/29/79, 10/30/79			
1300-1330	30	0	0
1336-1406	30	0	0
1412-1542	30	0	0
1450-1520	30	0	0
Test point 5, Storage bin, 10/29/79, 10/30/79			
0755-0825	30	0	0
1023-1053	30	0	0
0908-0938	30	0	0
0947-1017	30	0	0

TABLE 101

METHOD 9 - 6-MINUTE AVERAGES[a] FACILITY T

Run	TP-1 Primary crusher Observer 3	TP-1 Primary crusher Observer 4	TP-4 Cone crusher Observer 3	TP-4 Cone crusher Observer 4
1	4	8	18	15
2	6	7	21	14
3	9	8	22	14
4	3	3	23	15
5	5	5	19	13
6	10	8	17	11
7	4	3	20	13
8	9	5	15	8
9	8	7	15	8
10	7	7	15	9
11	8	8	16	6
12	8	8	6	7
13	8	6	10	11
14	13	8	17	16
15	10	6	19	16
16	13	8	18	15
17	10	5	15	15
18	9	4	16	13
19	10	6	18	16
20	6	5	13	14

[a] Data reported in percent opacity.

Table 102 and Figures 2 through 6 represent visible emission data given in this Appendix, on a basis of percent of total time of recorded visible emissions (e.g., in a Method 22 format) and on a basis of how opacity varied with time (e.g., in a Method 9 format). These observations were executed for fugitive emissions. The use of Method 22, as it applies to the proposed standard for non-metallic mineral processing plants would be applicable to all fugitive non-crushing sources of dust. This test would also be employed to check the effectiveness of a capture system, if used, at any process facility. Method 9 would be used for measurement of all crusher-related sources of dust. A description of each of the process facilities listed in Table 102 is given at the beginning of this Appendix.

Data for 64 observation periods of visible emissions readings covering 54 process facilities at 14 non-metallic processing plants is given in Table 102. All facilities observed were fugitive emission discharges from uncontrolled, hooded or wet suppression controlled facilities.

TABLE 102. SUMMARY OF VISIBLE EMISSIONS MEASUREMENTS FROM FUGITIVE SOURCES AT NON-METALLIC MINERALS PLANTS

Plant/Rock type processed		Date of test	Process facility	Accumulated observation time (minutes)	Accumulated emission time (minutes)	Percent of time with visible emissions
A	Crushed limestone	7/9/75	Baghouse discharge to conveyor	240	0	0
			Primary impact crusher discharge	240	4	1
			Conveyor transfer point	166	3	2
B	Crushed limestone	7/1/75	Scalping screen	287	45	15
			Surge bin	287	3	1
			Secondary cone crusher No. 1	231	23	10
			Secondary cone crusher No. 2	231	0	0
			Secondary cone crusher No. 3	231	0	0
			Hammer mill	287	0	0
			3-deck finishing screen (L)	107	4	4
			3-deck finishing screen (R)	107	0	0
		6/30/75	Two 3-deck finishing screens	120	86	72
D	Crushed stone	7/8/75	No. 1 tertiary gyrasphere cone crusher	170	0	0
			No. 2 tertiary gyrasphere cone crusher	170	0	0
			Secondary standard cone crusher	170	0	0
			Scalping screen	210	0	0
			Secondary (2-deck) sizing screen	210	0	0
			Secondary (3-deck) sizing screen	210	0	0
F	Traprock	8/26/76	Two tertiary crushers	65	0	0
			Four processing screens	180	0	0
			Conveyor transfer points	179	0	0

(continued)

TABLE 102 (continued)

Plant/Rock type processed	Date of test	Process facility	Accumulated observation time (minutes)	Accumulated emission time (minutes)	Percent of time with visible emissions
G Feldspar	9/27/76	Conveyor transfer point No. 1	80	0	0
		Conveyor transfer point No. 2	87	0	0
		Primary crusher	60	1	2
		Secondary crusher	60	0	0
		Conveyor transfer point No. 4	84	0	0
		Ball mill (feed end)	60	0	0
		Ball mill (discharge end)	60	0	0
		Indoor transfer point No. 1	60	0	0
		Indoor transfer point No. 2	60	0	0
		Indoor bucket elevator	60	0	0
		Truck loading	13	0	0
		Rail car loading	32	5	15
H Gypsum	10/27/76	Hammer mill	298	2	1
I Mica	9/30/76	Bagging operation	60	0	0
J Talc	10/21/76	Vertical mill	90	0	0
		Primary crusher	90	20	22
		Secondary crusher	150	4	3
		Bagger	150	13	9
		Pebble mill	90	6	7
N Kaolin	12/7/78	Rail car loading			
		Test 1	144	17	12
		Test 2	99	2	2
		Test 3	154	9	6

(continued)

TABLE 102 (continued)

Plant	Rock type processed	Date of test	Process facility	Accumulated observation time (minutes)	Accumulated emission time (minutes)[a]	Percent of time with visible emissions
P	Crushed Limestone (S)[b]	10/02/79	Secondary screen	60	0	0
			Transfer point	60	< 1	1
Q	Crushed Limestone (S)	10/10/79	Three process screens	270	2	< 1
R	Crushed Limestone (P)[c]	10/15/79	Three process screens	210	11	5
			Two transfer points	120	1	< 1
S	Crushed Granite (S)	10/23/79	Two process screens	240	10	4
			Two transfer points	240	< 1	0
T	Crushed Limestone (P)	10/29/79	Process screen	120	0	0
			Transfer point	120	3	2
			Storage bin	120	0	0

[a] Data from observer with highest readings.

[b] (S) = Stationary plant.

[c] (P) = Portable plant.

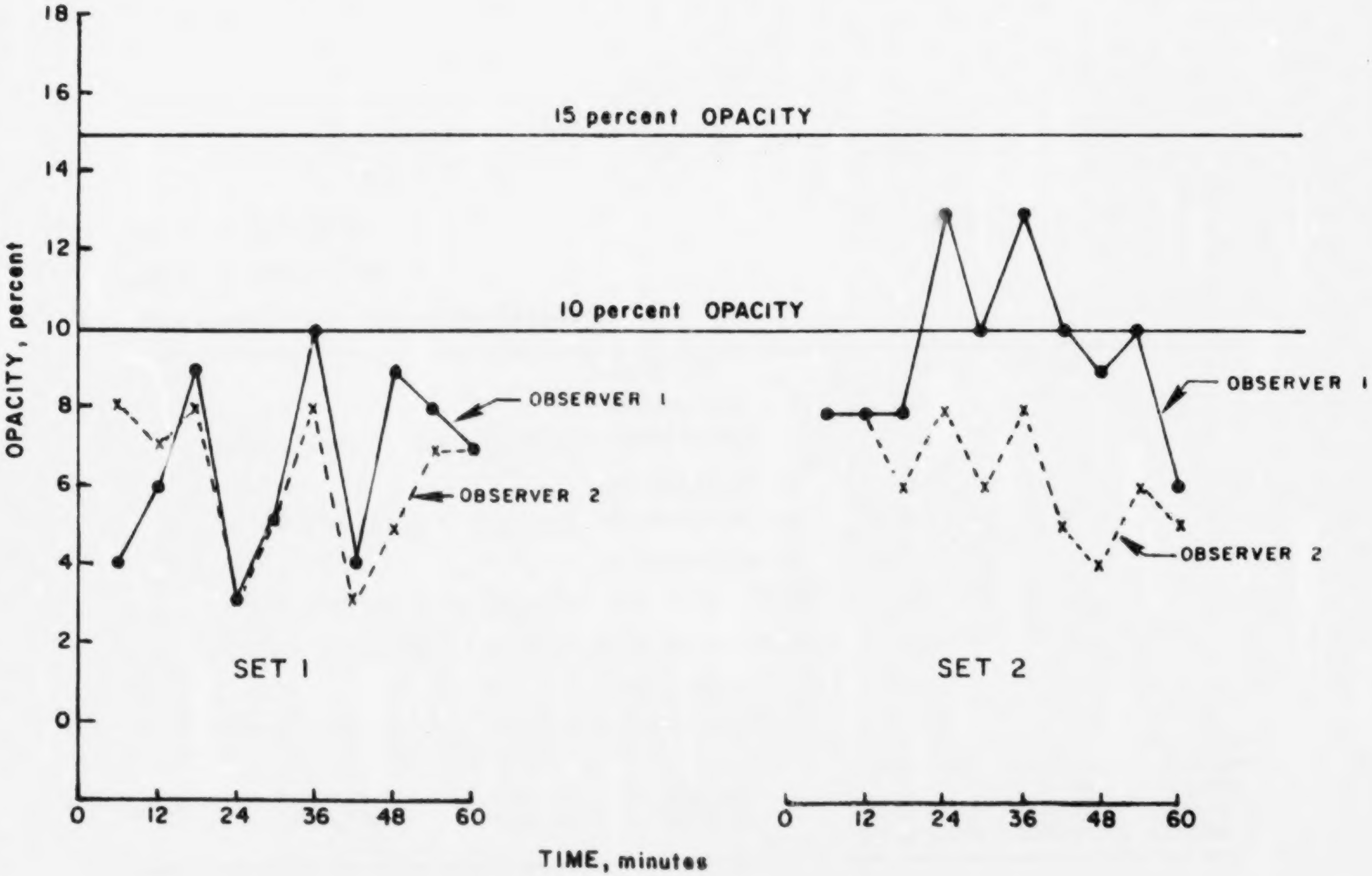


Figure C-2. Summary of visible emission measurements from best controlled fugitive primary crushing sources (portable-Facility T) by means of wet suppression (according to EPA Method 9).

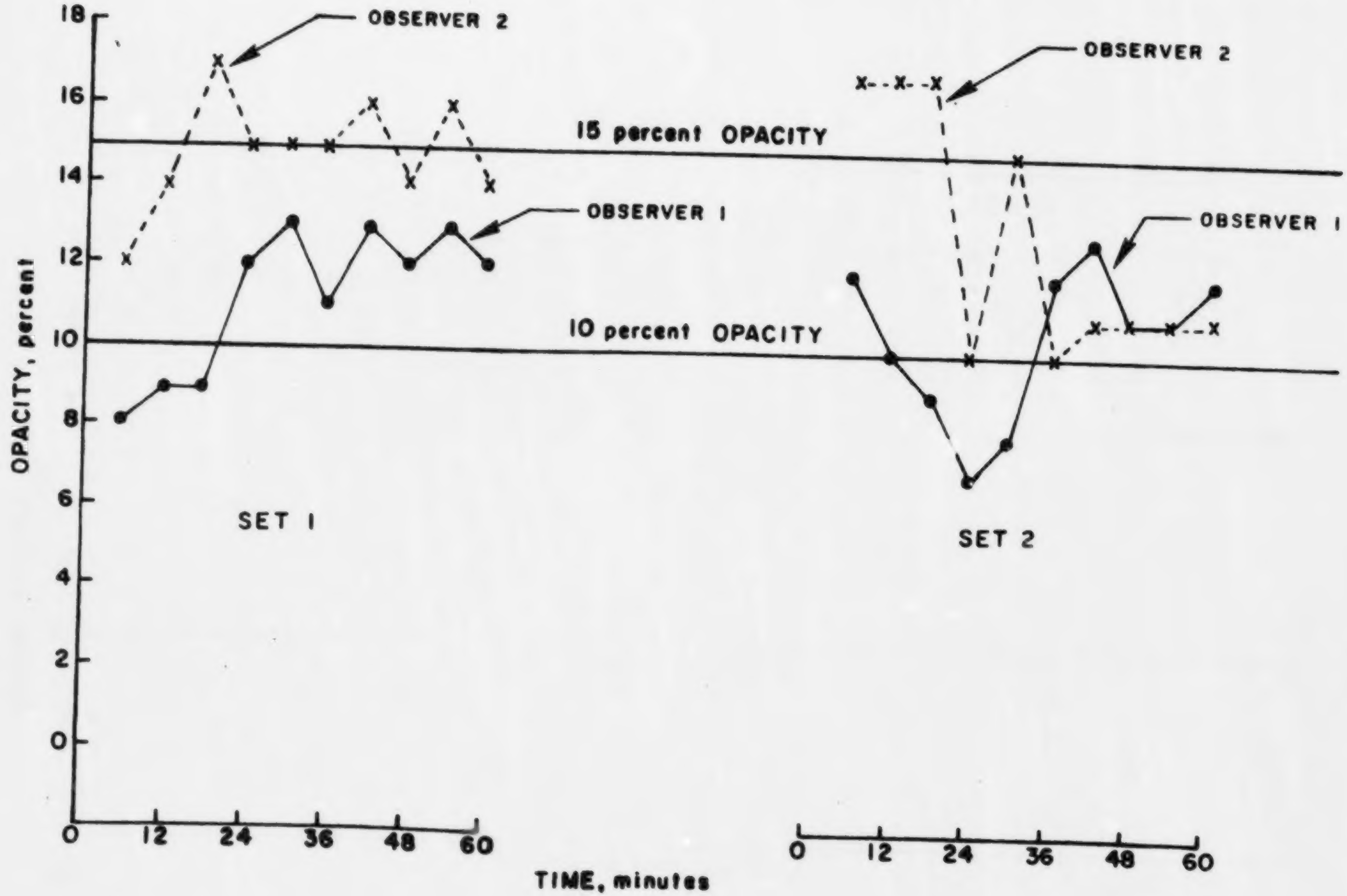


Figure C-3. Summary of visible emission measurements from best controlled fugitive secondary crushing source (portable-Facility R) by means of wet suppression (according to EPA Method 9).

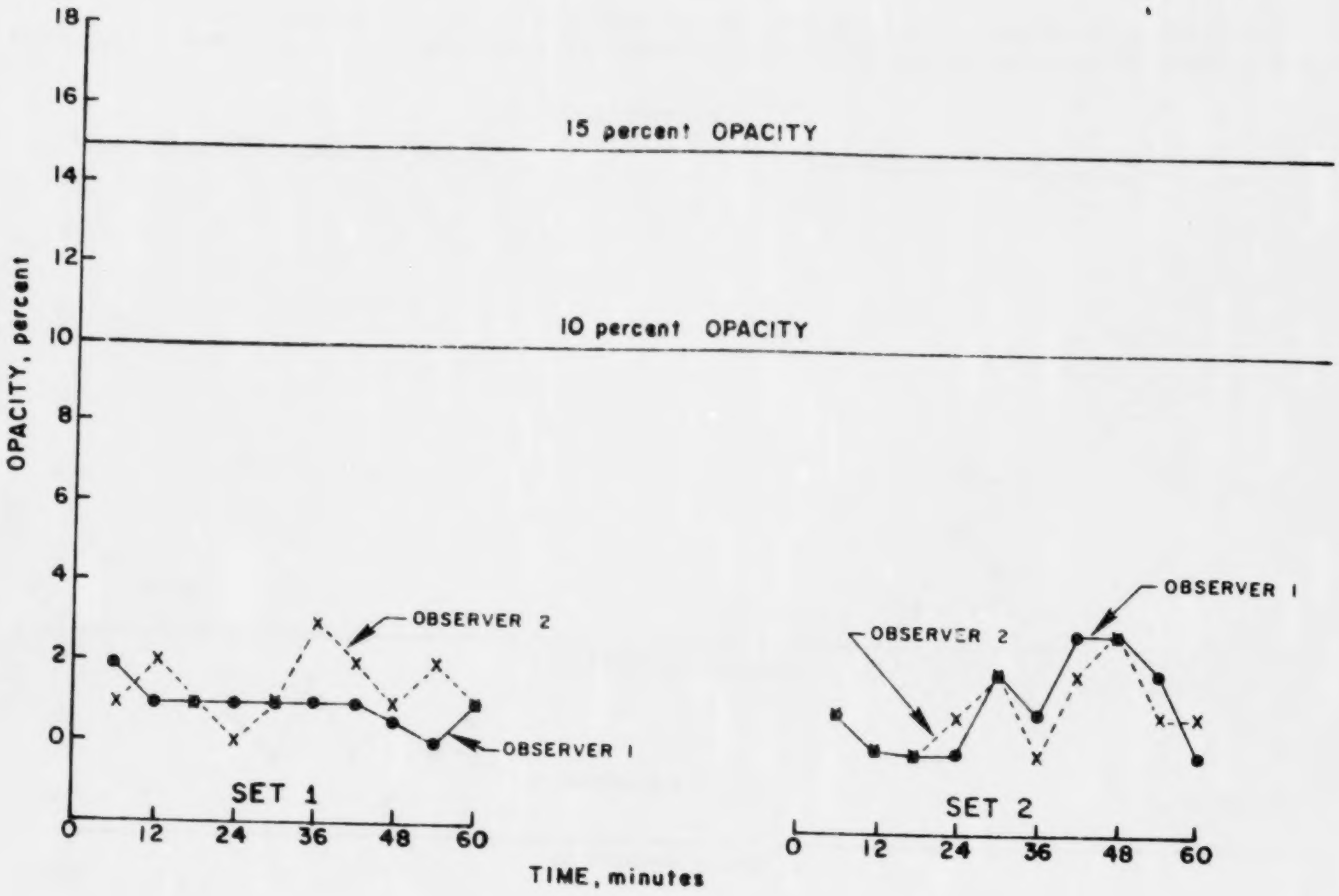


Figure C-4. Summary of visible emission measurements from best controlled fugitive primary crushing source (stationary-Facility S) by means of wet suppression (according to EPA Method 9).

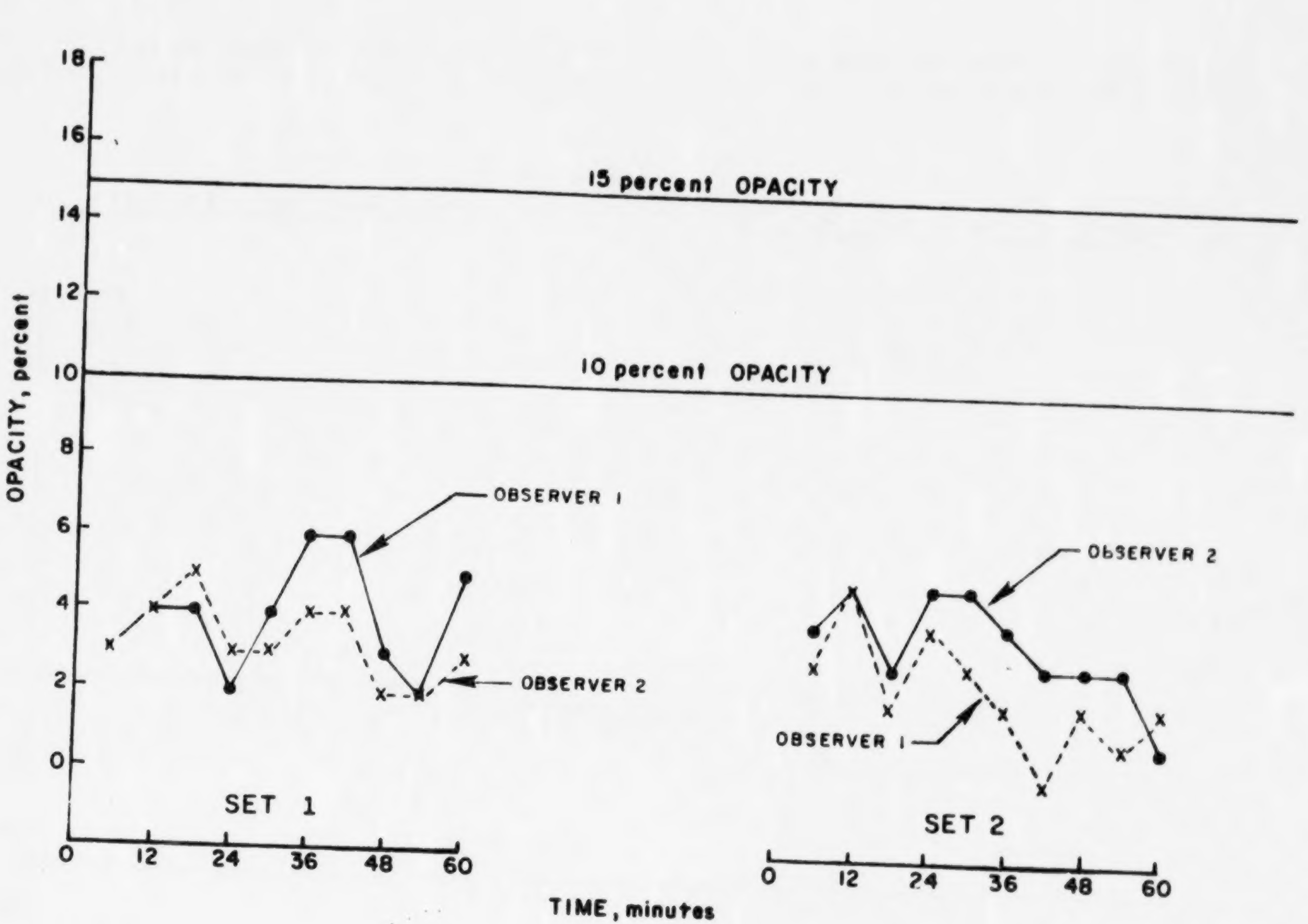


Figure C-5. Summary of visible emission measurement from best controlled fugitive secondary crusher (small, stationary-Facility S) by means of wet suppression (according to EPA Method 9).

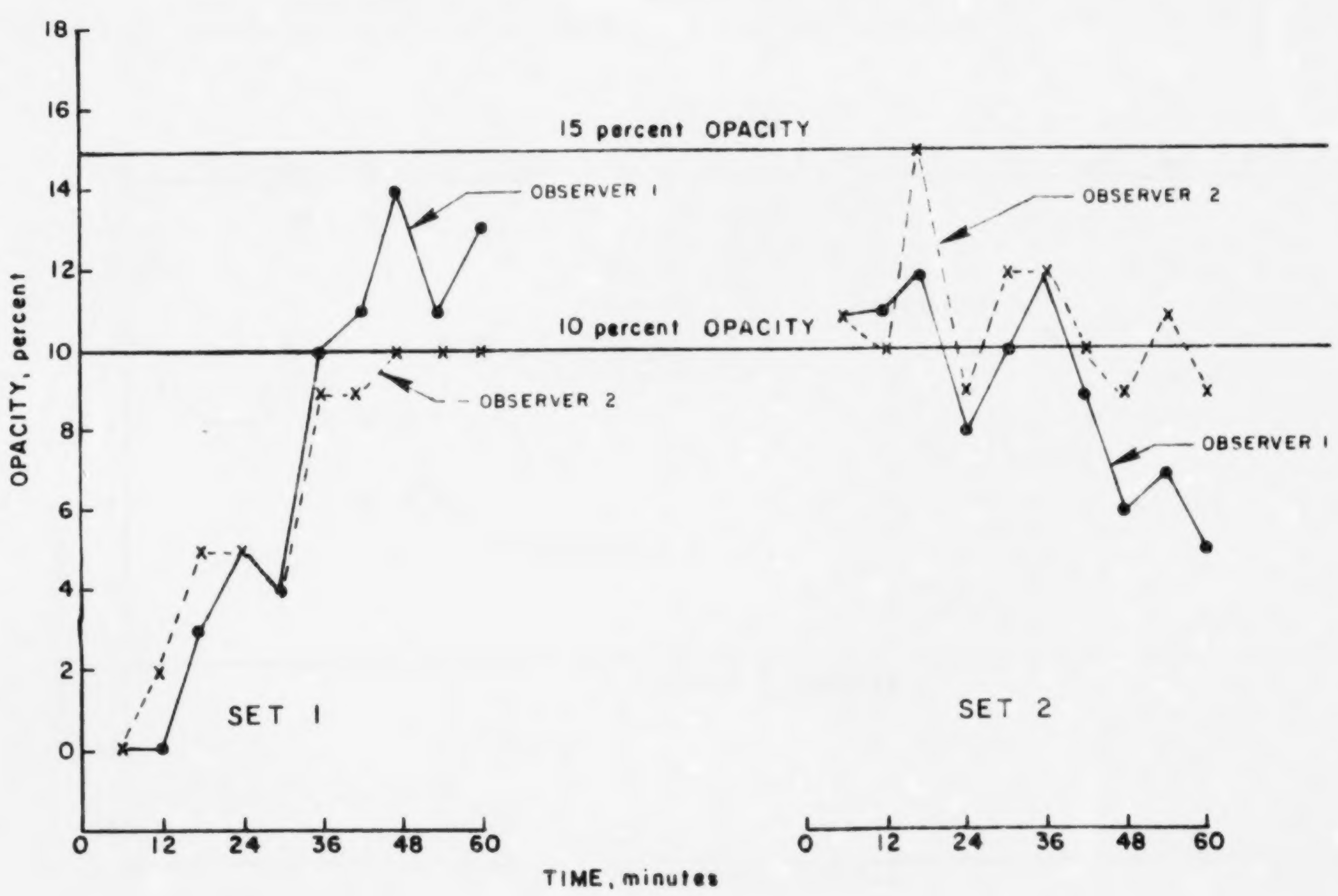


Figure C-6. Summary of visible emission measurements from best controlled fugitive secondary crushing source (large, secondary-Facility S) by means of wet suppression (according to EPA Method 9).

APPENDIX D

EMISSION MEASUREMENT AND CONTINUOUS MONITORING

D.1 EMISSION MEASUREMENT METHODS

For particulate matter and visible emissions measurements from stacks, EPA relies primarily upon Methods 5 and 9, which have been established as reference methods. The emission data from the non-metallic industry may be obtained using these reference methods as prescribed in the Federal Register. In addition, as the particulate concentrations are expected to be independent of temperature for this industry, Method 17 (in-stack filtration) is an acceptable particulate sampling method.

The one serious problem encountered during the testing of stacks in the non-metallic minerals industry was the low concentration levels of particulate. Some emissions tests resulted in particulate catches of less than 10 mg corresponding to 0.0005 gr/dscf. An EPA laboratory study showed that because of positive biases from the "clean-up" blank, results from tests where low concentration levels are encountered are biased toward the high side. This bias was no more than a factor of two for particulate catches down to 8 mg.

Data from an EPA report, "Additional Studies on Obtaining Replicate Particulate Samples From Stationary Sources," by William J. Mitchell, indicate that particulate catches of about 50 mg are adequate to insure an error of no more than 10 percent. Lower levels were not studied. Based on theoretical calculations, particulate weights as small as 12 mg were estimated to be sufficient to insure an error no greater than 10 percent.

D.2 MONITORING SYSTEMS AND DEVICES

The effluent streams from the non-metallic industry sources are at essentially ambient conditions. The visible emissions monitoring instruments found adequate for power plants would be applicable for this industry. These systems are covered by EPA performance standards contained in Appendix B of 40 CFR Part 60.

Equipment and installation costs are estimated to be $18,000 to $20,000 and annual operating costs, including data recording and reduction, are estimated at $8,000 to $9,000.

D.3 PERFORMANCE TEST METHODS

Either Method 5 or 17 for particulate matter is recommended as the performance test method. Due to low concentrations sometimes encountered, a minimum sample volume must be established to insure adequate amounts of particulate matter are collected to minimize recovery errors. This particulate catch amount is preferably 50 mg, but should be at least 25 mg. It is also recommended that sampling trains with higher sampling rates, which are allowed by Method 5 and are commercially available, be used to reduce sampling time and costs.

Sampling costs for a test consisting of three particulate runs, the number normally specified by performance test regulations, is estimated to be about $5,000 to $7,000. This estimate is based on sampling site modifications and testing being conducted by contractors. If in-plant personnel are used to conduct the test, the costs will be somewhat less.

Since the outlet gas streams from control devices used in this industry are generally well contained, no special sampling probelms are anticipated.

SUPPLEMENT A
ECONOMIC IMPACT ANALYSIS FOR PORTABLE PLANTS.

A.0 Introduction and Summary

After the preparation of Section 8, Economic Impact, of the background information document, comments were received from the crushed stone and sand and gravel industries concerning the impact analysis conducted for portable plants. Specifically, they commented that the costs of controlling portable processing plants with baghouses are substantially higher than those for fixed processing plants. The reasons given for the higher costs are the regular movement of the plants and the changes made in the operating configuration of the plants. Since these issues were not addressed in the original analysis, this analysis was prepared.

Because portable plants are used primarily in the crushed stone and sand and gravel industries, the impacts on these plants were evaluated by developing a Discounted Cash Flow (DCF) analysis for each model new plant size in these industries. DCF is an investment decision analysis which shows the economic feasibility of a planned capital investment project over the life of the project.

The DCF analysis was conducted by using conservative assumptions. Assumptions used include:

- the total of NSPS control costs were incremental costs; i.e., that there are no SIP control costs that the plant would have to incur in the absence of NSPS control.
- the plants operate at 1250 hours per year through the life of the project.
- NSPS control cost pass through is limited by competition of existing plants in the same industry which do not have to meet the NSPS.
- the new plant operates as a separate business entity and cannot expect to finance the control from another business activity or parent firm.

For new plants, the DCF analysis indicated that the 68 and 135 Mg/hr (75 and 150 ton/hr) portable plants in both industries are likely to be precluced by an NSPS. The DCF model was unable to determine a clear positive or negative investment decision for the 270 Mg/hr (300 ton/hr) portable plants in both industries. However, in view of the conservative assumptions used, they were judged to be economically feasible. All of the other plant sizes in the two industries are likely to be economically feasible after the promulgation of the NSPS.

A.1 INDUSTRY CHARACTERIZATION

A.1.1 General Profile

Portable mineral processing plants (portable plants) are used primarily by sand and gravel processors and crushed stone processors. The United States Geological Survey estimates that there were 3,285 portable plants in the sand and gravel industry and 1,232 portable plants in the crushed stone industry in 1978.[1] Portable plants account for 53 percent of total existing plants in the sand and gravel industry and 42 percent of total existing plants in the crushed stone industry.

Based on industry data, portable plants account for 40 to 50 percent of total annual mine output for the sand and gravel industry[2,3] and 30 to 40 percent of total annual mine output for the crushed stone industry.[4,5] In 1978, this amounted to 340-425 million megagrams (375-469 million tons) of sand and gravel and 260-347 million megagrams (287-382 million tons) of crushed stone.

The clay, gypsum, and pumice industries also use portable plants. However, these plants are used for specialized small output crushing operations which amount to an insignificant portion of total mine output for these industries.[6,7,8]

The major manufacturers of portable plant equipment are Iowa Manufacturing, Telsmith Division of Barber-Green, Portec, Universal Engineering, and Allis-Chalmers. These companies manufacture a variety of interchangeable portable crushers, screens, conveyor belt units, and combination systems which can be combined into an integrated portable plant that meets the requirements of the individual mineral processor.

The output capacity of manufactured portable plant equipment ranges from 45 megagrams per hour (50 tons per hour) to 998 megagrams per hour (1,100 tons per hour). A large majority of new and existing portable plants are in the 227 megagrams per hour (250 tons per hour) to 635 megagram per hour (700 tons per hour) output capacity range.

Portable plants are owned and operated by a variety of mineral processing firms. These firms range from the small, independent mineral processor with one portable plant to large construction materials companies (e.g. Moline Consumers Company, Flintkote) which may own and operate 12 or more portable plants.

Construction companies also purchase portable plant equipment for large and/or remote site construction projects. The portable plant equipment is used to supply material for a specific construction project and is usually sold or scrapped after completion of the project.[9,10,11]

The contract processor owns portable plant equipment and contracts mineral processing services to a community or another firm. These services may be contracted for during periods of high product demand when a mineral processor's output capacity is limited or when a community or firm requires a supply of construction material. A contract processor may cover a geographical area which encompasses several states.[12,13]

A.1.2 Geographic Distribution

Portable plants are used throughout the nation. However, over 70 percent of existing portable plants are located west of the Mississippi River.[14] The popularity of portable plants in the western and mid-western states is due mostly to the demand for crushed stone and sand and gravel in sparsely populated areas. Such areas can not be economically served by fixed plants due to high transportation cost for crushed stone and sand and gravel.

The crushed stone and sand and gravel industries can be divided into three basic national regions based on portable plant/fixed plant usage (see Figure 1). These regions are:

Region I - In this region, which encompasses the states in the Northeast and Southeast and most of California, over 80 percent of mine output for the sand and gravel and crushed stone industries is from fixed plants. The region has a relatively high population density and well established product markets for construction materials. Portable plants are used at large construction projects (i.e. dams, highways) and to supplement mine output at fixed operations, particularly during periods of high

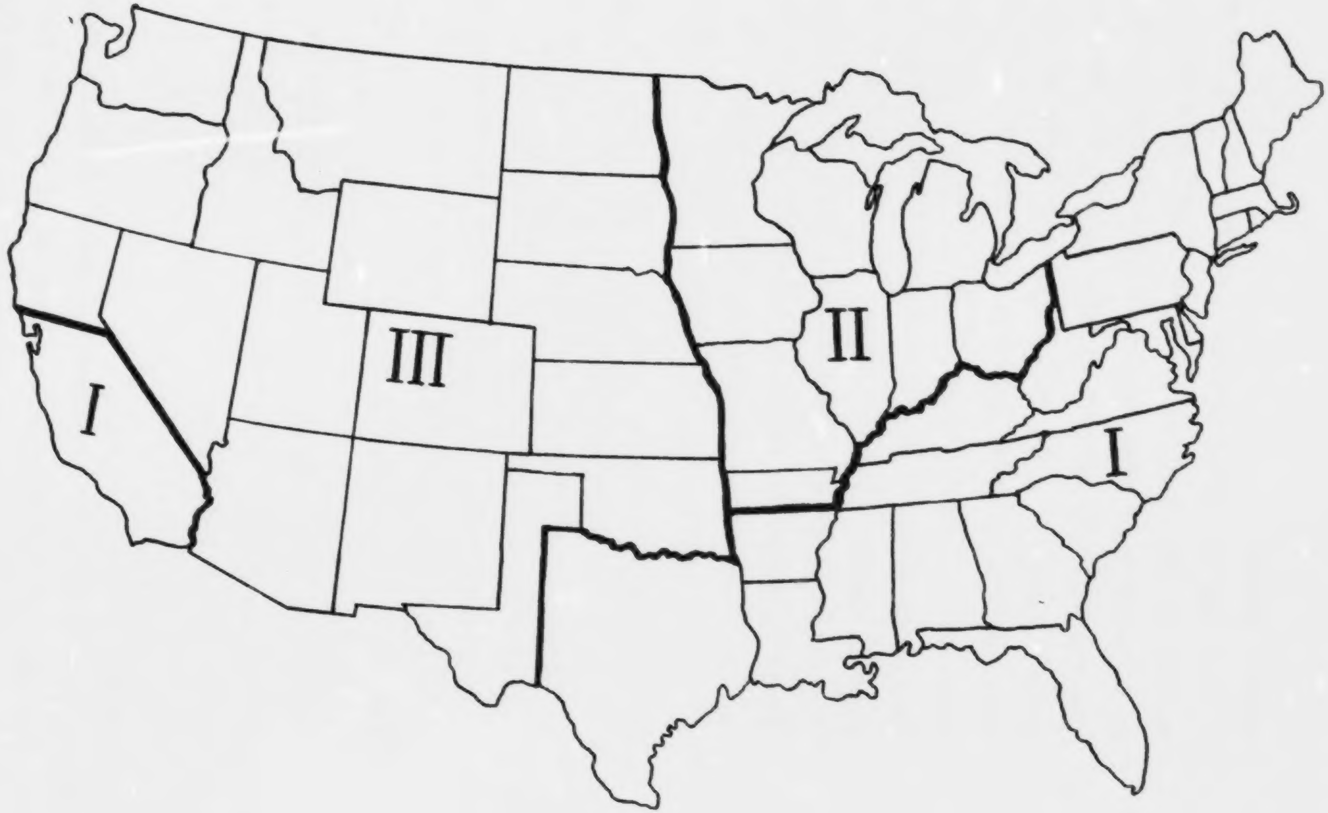


Figure 1 - Regional Distribution of Portable and Fixed Plants for the Crushed Stone and Sand and Gravel Industries.

product demand.

Region II - In this region, which encompasses most of the Midwest section of the country, portable plants account for 20 to 40 percent of mine output for the crushed stone industry and 30 to 50 percent of mine output for the sand and gravel industry. The region has many large metropolitan areas with well established product markets for construction materials. However, some of the areas are sparsely populated and portable plants are used to meet the fluctuating product demand in these areas. Product transportation costs for sand and gravel and crushed stone, which range from \$0.08 to \$0.15 per megagram kilometer (\$0.12 to \$0.22 per ton mile) nationally, make the establishment of a fixed plant economically unattractive in parts of this region and most of Region III.

Region III - In this region, which encompasses the Western states and northern California, portable plants account for over 50 percent of mine output for the sand and gravel and crushed stone industries. In New Mexico, Utah, Wyoming, Colorado, and Nebraska, over 80 percent of mine output for both industries is from portable plants. The region is sparsely populated and product demand for construction materials is usually not high enough to warrant the establishment of a fixed plant.

The portable plant/stationary plant usage distribution, as described above, is not expected to change in the near future.[14]

A.1.3 Industry Trends

The projected growth rate for the sand and gravel industry through 1985 is 1.0 percent per year, while the growth in crushed stone over the same period is 4.0 percent per year.[15] These growth projections are for the entire industry; separate projections for the portable plant segments of each industry are unavailable.

Based on mineral processing equipment sales, more portable plant equipment is sold per year than fixed plant equipment. However, the total output capacity of the portable plant equipment is less than the total output capacity of the fixed plant equipment.[10,14] This equipment sales trend, which is expected to continue for the near future, indicates that the average new portable plant would have a lower output capacity than the average new fixed plant.

A.1.4 Methods of Operation

The mobility of portable crushed stone plants allows portable plant operators to move their plants according to either of two major methods: among various quarry sites, or both among, as well as within, quarries. With regard to the former, the operator may choose to move a single plant to a number of quarries over the year; however, once set at a site, several haul trucks are used to transport blasted rock to the primary crusher. However, other operators may elect to move not only to different quarries but also within an individual quarry as well. Movement within quarries allows the plant to follow blasting activities as they take place at various locations around larger quarries. In effect, the movement of portable plants within individual quarries reduces the need for haul trucks to transport newly blasted rock to the primary crusher. While the decision to move about or remain stationary within a quarry may depend upon the physical condition of the quarry and/or the individual preferences of operators, the economic analysis has recognized both methods of operation.

A.2 COST ANALYSIS

A.2.1 Model Portable Plants

Model portable plants have been developed which describe the types of equipment and size ranges for portable plants in the sand and gravel and crushed stone processing industries. The equipment selected for these model portable plants are:

I. Portable sand and gravel plant
    1. Primary crusher
    2. Secondary crusher and associated screen
    3. Final screen
    4. Conveyor belts

II. Portable crushed stone plant
    1. Primary crusher
    2. Secondary crusher and associated screen
    3. Tertiary crusher and associated screen
    4. Final screen
    5. Conveyor belts

Five output capacities were chosen for both the sand and gravel and crushed stone model portable plants. The five output capacities used are 68, 135, 270, 540, and 817 megagrams per hour (75, 150, 300, 600, and 900 tons per hour). Specific sizes of portable crushing and screening equipment have been combined to meet the output capacities of the model portable plants. Tables 1 through 5 list the equipment requirements for the model portable plants along with energy usage and air volume requirements. The equipment size ranges listed in Tables 1 through 5 represent minimum and maximum product outputs for each piece of processing equipment.

Processing equipment for a portable plant can be arranged in a variety of operating configurations at the mine site. Two basic operating configurations are used for the model portable plants. One configuration is a straight line setup in which the portable plant equipment lies in a basic straight line. The second configuration is an "L" shaped setup. In this configuration the final screen is situated at a right angle from the secondary screen at the portable sand and gravel plant, and the tertiary crusher/screen unit and final screen are situated at a right angle from the secondary screen at the portable crushed stone plant.

TABLE 1

MODEL PORTABLE PLANT EQUIPMENT REQUIREMENTS

68 megagrams per hour
(75 tons per hour)

	Size[a]	Energy Usage[b]	Air Volume[c]
1. Primary crusher	54 - 227 (60 - 250)	56.0 (75)	43 (1500)
2. Secondary crusher	68 - 104 (75 - 115)	74.6 (100)	43 (1500)
3. Secondary screen	45 - 181 (50 - 200)	14.9 (20)	127 (4500)
4. Tertiary crusher	109 - 136 (120 - 150)	111.9 (150)	43 (1500)
5. Tertiary screen	45 - 181 (50 - 200)	14.9 (20)	99 (3500)
6. Final screen	45 - 181 (50 - 200)	14.9 (20)	127 (4500)

[a] Given in megagrams per hour with tons per hour in parenthesis

[b] Given in kilowatts with horsepower in parenthesis

[c] Given in cubic meters per minute with actual cubic feet per minute in parenthesis

References: Portable processing equipment brochures from Iowa Manufacturing Company, Telsmith Division of Barber-Green, and Allis Chalmers.

TABLE 2

MODEL PORTABLE PLANT EQUIPMENT REQUIREMENTS

135 megagrams per hour
(150 tons per hour)

	Size[a]	Energy Usage[b]	Air Volume[c]
1. Primary crusher	91 - 363 (100 - 400)	74.6 (100)	99 (3500)
2. Secondary crusher	181 - 272 (200 - 300)	93.3 (125)	99 (3500)
3. Secondary screen	45 - 181 (50 - 200)	14.9 (20)	142 (5000)
4. Tertiary crusher	136 - 227 (150 - 250)	167.9 (225)	57 (2000)
5. Tertiary screen	45 - 181 (50 - 200)	14.9 (20)	113 (4000)
6. Final screen	45 - 181 (50 - 200)	14.9 (20)	142 (5000)

[a] Given in megagrams per hour with tons per hour in parenthesis

[b] Given in kilowatts with horsepower in parenthesis

[c] Given in cubic meters per minute with actual cubic feet per minute in parenthesis

References: Portable processing equipment brochures from Iowa Manufacturing Company, Telsmith Division of Barber-Green, and Allis Chalmers.

TABLE 3

MODEL PORTABLE PLANT EQUIPMENT REQUIREMENTS

270 megagrams per hour
(300 tons per hour)

	Size[a]	Energy Usage[b]	Air Volume[c]
1. Primary crusher	136 - 363 (150 - 400)	93.3 (125)	113 (4000)
2. Secondary crusher	227 - 454 (250 - 500)	111.9 (150)	113 (4000)
3. Secondary screen	181 - 363 (200 - 400)	22.4 (30)	198 (7000)
4. Tertiary crusher	272 - 363 (300 - 400)	186.5 (250)	142 (5000)
5. Tertiary screen	181 - 363 (200 - 400)	22.4 (30)	198 (7000)
6. Final screen	181 - 363 (200 - 400)	14.9 (20)	198 (7000)

[a] Given in megagrams per hour with tons per hour in parenthesis

[b] Given in kilowatts with horsepower in parenthesis

[c] Given in cubic meters per minute with actual cubic feet per minute in parenthesis

References: Portable processing equipment brochures from Iowa Manufacturing Company, Telsmith Division of Barber-Green, and Allis Chalmers.

TABLE 4

MODEL PORTABLE PLANT EQUIPMENT REQUIREMENTS

540 megagrams per hour
(600 tons per hour)

	Size[a]	Energy Usage[b]	Air Volume[c]
1. Primary crusher	408 - 635 (450 - 700)	186.5 (250)	142 (5000)
2. Secondary crusher	408 - 635 (450 - 700)	223.8 (300)	142 (5000)
3. Secondary screen	363 - 680 (400 - 750)	29.8 (40)	227 (8000)
4. Tertiary crusher	408 - 635 (450 - 700)	261.1 (350)	170 (6000)
5. Tertiary screen	363 - 680 (400 - 750)	29.8 (40)	227 (8000)
6. Final screen	363 - 680 (400 - 750)	29.8 (40)	227 (8000)

[a] Given in megagrams per hour with tons per hour in parenthesis

[b] Given in kilowatts with horsepower in parenthesis

[c] Given in cubic meters per minute with actual cubic feet per minute in parenthesis

References: Portable processing equipment brochures from Iowa Manufacturing Company, Telsmith Division of Barber-Green, and Allis Chalmers.

TABLE 5

MODEL PORTABLE PLANT EQUIPMENT REQUIREMENTS

817 megagrams per hour
(900 tons per hour)

	Size[a]	Energy Usage[b]	Air Volume[c]
1. Primary crusher	726 - 907 (800 - 1000)	298.4 (400)	170 (6000)
2. Secondary crusher	635 - 907 (700 - 1000)	298.4 (400)	170 (6000)
3. Secondary screen	816 - 998 (900 - 1100)	37.3 (50)	283 (10,000)
4. Tertiary crusher	816 - 998 (900 - 1100)	298.4 (400)	170 (6000)
5. Tertiary screen	816 - 998 (900 - 1100)	37.3 (50)	283 (10,000)
6. Final screen	816 - 998 (900 - 1100)	37.3 (50)	283 (10,000)

[a] Given in megagrams per hour with tons per hour in parenthesis

[b] Given in kilowatts with horsepower in parenthesis

[c] Given in cubic meters per minute with actual cubic feet per minute in parenthesis

References: Portable processing equipment brochures from Iowa Manufacturing Company, Telsmith Division of Barber-Green, and Allis Chalmers.

The average output capacity for new and existing portable sand and gravel plants in the eastern U.S. is between 227 and 270 megagrams per hour (250 and 300 tons per hour). The installed capital cost for these plants would be between approximately $0.45 million and $1 million.[9,10,16,17,18] The average output capacity for new and existing portable sand and gravel plants in the western U.S. is between 540 and 635 megagrams per hour (600 and 700 tons per hour). The installed capital cost for these plants would be at least $1 million.[9,10,16,17,18]

The average output capacity for new and existing portable crushed stone plants is between 227 and 270 megagrams per hour (250 and 300 tons per hour). The installed capital cost for these plants is between $0.6 million and $1.3 million.[9,10,16,17,18]

The cost per ton of material processed by a portable plant is higher than the cost per ton of material processed by a similar output capacity fixed plant. This higher cost is primarily due to higher maintenance costs and a lower annual operating schedule for portable plants. Portable plants are designed for mobile transport and lack some of the structural strength of fixed plants. Thus, portable plants have shorter operating lives than fixed plants and require more man-hours to maintain. On the average, portable plants operate fewer hours per year (1250 to 1600 hours)[16,17,18,19] than fixed plants (2000 hours). This difference is due primarily to the downtime associated with the movement of portable plants. Due to this, total annual costs for a portable plant must be recovered on a lower total product output compared to similar output capacity fixed plants.

A.2.2 Movement

There are two basic types of portable plant movements. One type involves transporting the entire portable plant from one quarry to another. On the average, this type of move occurs four times per year.[16,17,18,19,20] The second type of portable plant move is an in-quarry operation in which the primary crusher is moved near the mined material along the highwall. In this mode, the mineral processor establishes a core operating configuration in the quarry and transports the product from the primary crusher to the core operating configuration by a conveyor belt. This eliminates the need for haul trucks for the transporting of mined material from the highwall to the portable plant. In-quarry moves of the primary crusher may occur up to 24 times per year. This type of move is characteristic of the small, independent processor. The larger firms in the sand and gravel and crushed stone industries usually employ haul trucks to transport mined material from the highwall to the portable plant, instead of moving the primary crusher to the mined material.[21,22] Table 6 lists average movement parameters and associated costs for a typical portable plant. These parameters and costs were obtained from mineral processors who use portable plants. Also listed in this table are estimated movement parameters and associated costs for the baghouse systems considered in this analysis. The baghouse movement costs are based on rental charges for equipment necessary for an offsite move. A mineral processor may decide to purchase a crane for moving the baghouse systems and/or haul trucks to minimize the amount of in-quarry moves necessary. The cost of a crane is $80,000 and the cost of a 20 megagram (22 ton) capacity haul truck is $50,000.

A.2.3 Control Options

Two control options are used for the model portable plants. The options are:

> Option I - In this option, one baghouse would be used to control the entire portable plant for the 68, 135, and 270 megagrams per hour (75, 150, and 300 tons per hour) model plants. For the 540 and 817 megagrams per hour (600 and 900 tons per hour) model plants, the primary crusher would be ducted to one baghouse and all other pieces of equipment would be ducted to a second baghouse.
>
> Option II - In this option, the following pieces of equipment or groupings of equipment would have their own baghouse for all output sizes of model plants:

TABLE 6

DATA ON A PORTABLE PLANT SITE CHANGE

Portable Plant		
A. Plant size	270 megagrams per hour (300 tons per hour)	
B. Average operating schedule	1,250 hours per year	
C. Product	Sand & gravel or crushed stone	
D. Data on a mine site change		
1. Time required to complete move	1-3 weeks	
2. Equipment setup time	200-400 man hours	
Cost[a]		$ 2,400- 4,800
3. Equipment dismantling time	200-400 man hours	
Cost[a]		2,400- 4,800
4. Transportation cost[b]		3,000- 9,000
Driver cost[a]		2,400- 7,200
E. Estimated total cost of a site change		$10,200-25,800
Control System		
A. Control system setup time	48-72 man hours	
Cost[a]		$ 576- 864
B. Control system dismantling time	48-72 man hours	
Cost[a]		576- 864
C. Small crane rental:		
1. Setup time	24-36 hours	
Cost[c]		2,400- 3,600
2. Dismantling time	24-36 hours	
Cost[c]		2,400- 3,600
D. Transportation cost[d]		1,600- 4,800
Driver cost[a]		960- 2,880
E. Estimated total cost of moving a control system		$ 8,512-16,608

---

[a] Based on an average wage rate of $12.00/hour.

[b] Based on a truck rental cost of $600/truck/week. Five trucks required.

[c] Based on a small crane rental cost of $100/hour.

[d] Based on a truck and flat bed trailer rental cost of $800/truck and trailer unit/week. Two tractor trailer units required.

1. Primary crusher
2. Secondary crusher and associated screen
3. Tertiary crusher and associated screen
4. Final screen

For both options, emissions from conveyor belt transfer points are hooded and ducted to the baghouse systems.

Costs are presented for the two baghouse control options used for controlling particulate emissions from the five output capacities of the two model portable plants. The control costs have been based on technical parameters associated with the control system used. These parameters are listed in Table 7.

These costs cannot be assumed to reflect control costs for any given installation. Estimating control costs for an actual installation requires performing detailed engineering studies. Nonetheless for purposes of this analysis, control costs are considered to be sufficiently accurate.

The control costs have been obtained from a variety of sources. These sources include vendors of air pollution control equipment, industrial contractors, metal work contractors, and published reports on air pollution control system costs.[23,24,25,26,27,28]

Two cost parameters have been developed: installed capital and total annualized cost. The installed capital costs for each emission control system include the purchased cost of the major and auxiliary equipment, costs for site preparation and equipment installation, and design engineering costs. The capital costs in this section reflect third quarter 1979 prices for equipment, installation materials, and installation labor and are based on pulse-jet baghouses with a pressure differential of 1.5 kPa (6 in. W.G.) and an air to cloth ratio of seven to one. The filter bags for the baghouses are polypropylene.

The total annualized costs consist of direct operating costs and annualized capital charges. Direct operating costs include fixed and variable annual costs, such as:

- Labor and materials required for operation of the control equipment
- Maintenance labor and materials

TABLE 7

TECHNICAL PARAMETERS USED IN DEVELOPING CONTROL SYSTEM COSTS

Parameter	Value
1. Temperature	Ambient
2. Volumetric flowrate	See tables 1 through 5, 9, and 10.
3. Moisture content	2 percent (by volume)
4. Particulate loadings:	
A. Inlet	12.8 g/Nm^3 (5.6 grains/scf)
B. Outlet	0.050 g/Nm^3 (0.02 grains/scf)
5. Plant capacities	68, 135, 270, 540, and 817 megagrams per hour (75, 150, 300, 600, and 900 tons per hour)
6. Operating schedule	1,250 hours per year

- Dust disposal
- Replacement parts

Dust disposal costs apply to the baghouse control systems A unit cost of $4.40 per megagram ($4.00 per ton) of particulate collected is used to cover the costs of trucking the collected particulate to an on-site disposal point.

The annualized capital charges account for depreciation, interest, administrative overhead, property taxes, and insurance. The depreciation and interest have been computed by use of a capital recovery factor. The capital recovery factor depends on the depreciable life of the control system and the interest rate. For the portable plant analysis, a seven year depreciable life for the control system and a 10 percent interest rate are used. This gives a capital recovery factor of 20.54 percent. Administrative overhead, taxes, and insurance have been fixed at an additional four percent of the installed capital cost per year. Table 8 lists the annualized capital cost factors used.

A.2.4. New Portable Plants

Two model portable plants have been developed for costing purposes. One is a portable sand and gravel plant and the other is a portable crushed stone plant. The control option used to achieve the emission level of 0.05 grams per dry standard cubic meter (0.02 grains per dry standard cubic foot) is a baghouse system. For an uncontrolled emission rate of 12.8 grams per dry standard cubic meter (5.6 grains per dry standard cubic foot) this control option is 99.6 percent efficient in removing particulate at the model portable plants. The size and number of baghouses required to achieve the emission limit vary according to the output capacity of the portable plant. The air flowrates for the baghouse systems are listed in Tables 9 and 10.

Tables 11 through 15 list installed capital, direct operating, annualized capital, and total annualized costs for each of the baghouse systems installed in the two model portable plants. The five portable plant output capacities for which costs have been developed represent the output capacities applicable to portable plants in the sand and gravel

TABLE 8

ANNUALIZED CAPITAL COSTS

1. Operating labor	\$12.00/hour
2. Annual maintenance	5 percent of the total installed capital cost for each control system
3. Utilities: Electric power	\$0.04/kWh
4. Replacement parts: Polypropylene bags[a]	\$8.00/m^2 (\$0.75/ft^2)
5. Capital recovery factor	14.60 percent of total cost for each control system
6. Taxes, insurance, and administration charges	4 percent of total installed capital cost for each control system
7. Estimated life of baghouse control system	7 years

[a] Three quarters of total filter bag area is replaced every year

TABLE 9

BAGHOUSE CONTROL SYSTEM FOR MODEL PORTABLE PLANTS[a,b]

	Output		
	68 Mg/hr (75 tph)	135 Mg/hr (150 tph)	270 Mg/hr (300 tph)
Option I			
1. Sand and Gravel Operation -			
A. Gas flowrate: Meters^3/minute	340	481	623
(ACFM)[c]	(12,000)	(17,000)	(22,000)
B. Pressure differential	6" W.G.[d]	6" W.G.	6" W.G.
2. Crushed Stone Operation -			
A. Gas flowrate: Meters^3/minute	481	651	963
(ACFM)	(17,000)	(23,000)	(34,000)
B. Pressure differential	6" W.G.	6" W.G.	6" W.G.

---

[a] Temperature -- ambient

[b] Average moisture content -- 2%

[c] ACFM -- Actual Cubic Feet Per Minute

[d] W.G. -- Water Gauge

TABLE 9 (con't)

BAGHOUSE CONTROL SYSTEM FOR MODEL PORTABLE PLANTS[a,b]

	Output 540 Mg/hr (600 tph)	 817 Mg/hr (900 tph)
Option I		
1. Sand and Gravel Operations		
Baghouse for primary crusher		
A. Gas flowrate: Meters^3/minute	142	170
(ACFM)[c]	(5,000)	(6,000)
B. Pressure differential	6" W.G.[d]	6" W.G.
Baghouse for secondary crusher, secondary screener and final screener		
A. Gas flowrate: Meters^3/minute	595	736
(ACFM)	(21,000)	(26,000)
B. Pressure differential	6" W.G.	6" W.G.
2. Crushed Stone Operation		
Baghouse for primary crusher		
A. Gas flowrate: Meters^3/minute	142	170
(ACFM)	(5,000)	(6,000)
B. Pressure differential	6" W.G.	6" W.G.
Baghouse for secondary crusher, sceondary screener, tertiary crusher, tertiary screener and final screener		
A. Gas flowrate: Meters^3/minute	991	1,189
(ACFM)	(35,000)	(42,000)
B. Pressure differential	6" W.G.	6" W.G.

---

[a] Temperature -- ambient

[b] Average moisture content -- 2%

[c] ACFM -- Actual Cubic Feet Per Minute

[d] W.G. -- Water Gauge

TABLE 10

BAGHOUSE CONTROL SYSTEM FOR MODEL PORTABLE PLANTS[a,b]

	Output				
	68 Mg/hr (75 tph)	135 Mg/hr (150 tph)	270 Mg/hr (300 tph)	540 Mg/hr (600 tph)	817 Mg/hr (900 tph)
Option II					
Baghouse for primary crusher					
A. Gas flowrate: Meters^3/minute	57	85	113	142	170
(ACFM)[c]	(2,000)	(3,000)	(4,000)	(5,000)	(6,000)
B. Pressure differential	6" W.G.[d]	6" W.G.	6" W.G.	6" W.G.	6" W.G.
Baghouse for secondary crusher and screener					
A. Gas flowrate: Meters^3/minute	142	227	283	368	453
(ACFM)	(5,000)	(8,000)	(10,000)	(13,000)	(16,000)
B. Pressure differential	6" W.G.	6" W.G.	6" W.G.	6" W.G.	6" W.G.
Baghouse for tertiary crusher and screener					
A. Gas flowrate: Meters^3/minute	142	170	340	396	453
(ACFM)	(5,000)	(6,000)	(12,000)	(14,000)	(16,000)
B. Pressure differential	6" W.G.	6" W.G.	6" W.G.	6" W.G.	6" W.G.
Baghouse for final screener					
A. Gas flowrate: Meters^3/minute	142	170	227	227	283
(ACFM)	(5,000)	(6,000)	(8,000)	(8,000)	(10,000)
B. Pressure differential	6" W.G.	6" W.G.	6" W.G.	6" W.G.	6" W.G.

---

[a] Temperature -- ambient

[b] Mositure content -- 2%

[c] Actual Cubic Feet Per Minute

[d] W.G. -- Water Gauge

TABLE 11

BAGHOUSE CONTROL SYSTEM COSTS FOR A 68 MEGAGRAMS (75 TONS) PER HOUR MODEL PORTABLE PLANT

	Option I		Option II	
	Sand and Gravel	Crushed Stone	Sand and Gravel	Crushed Stone
1. Gas flowrate -				
A. Meters^3/minute	340	481	340	481
B. (ACFM)^a	(12,000)	(17,000)	(12,000)	(17,000)
2. Installed capital costs	$87,590	$131,890	$99,735	$138,290
3. Annualized costs -				
A. Annualized capital charges	$21,495	$32,365	$24,475	$33,940
B. Direct operating cost	12,405	18,333	13,620	19,973
C. Total	$33,900	$50,698	$38,095	$53,913
4. Cost effectiveness -				
A. $/megagram of particulate removed	$104	$110	$117	$115
B. ($/ton of particulate removed)	($95)	($100)	($106)	($104)

a - Actual Cubic Feet per Minute

TABLE 12

BAGHOUSE CONTROL SYSTEM COSTS FOR A 135 MEGAGRAMS (150 TONS) PER HOUR MODEL PORTABLE PLANT

	Option I		Option II	
	Sand and Gravel	Crushed Stone	Sand and Gravel	Crushed Stone
1. Gas flowrate -				
A. Meters^3/minute	481	651	481	651
B. (ACFM)^a	(17,000)	(23,000)	(17,000)	(23,000)
2. Installed capital costs	$101,150	$146,970	$114,595	$156,440
3. Annualized costs -				
A. Annualized capital charges	$24,826	$36,070	$28,125	$38,395
B. Direct operating cost	15,259	21,475	16,604	22,422
C. Total	$40,085	$57,545	$44,729	$60,817
4. Cost effectiveness -				
A. $/megagram of particulate removed	$87	$92	$97	$98
B. ($/ton of particulate removed)	($79)	(84)	($88)	($89)

a - Actual Cubic Feet per Minute

TABLE 13

BAGHOUSE CONTROL SYSTEM COSTS FOR A 270 MEGAGRAMS (300 TONS) PER HOUR MODEL PORTABLE PLANT

	Option I		Option II	
	Sand and Gravel	Crushed Stone	Sand and Gravel	Crushed Stone
1. Gas flowrate -				
A. Meters^3/minute	623	963	623	963
B (ACFM)^a	(22,000)	(34,000)	(22,000)	(34,000)
2. Installed capital costs	$138,175	$203,600	$139,710	$200,245
3. Annualized costs -				
A. Annualized capital charges	$33,915	$49,964	$34,290	$49,140
B. Direct operating cost	20,337	29,650	20,470	29,315
C. Total	$54,252	$79,614	$54,760	$78,455
4. Cost effectiveness -				
A. $/megagram of particulate removed	$91	$86	$92	$85
B. ($/ton of particulate removed)	($83)	($78)	($83)	($77)

a - Actual Cubic Feet per Minute

TABLE 14

BAGHOUSE CONTROL SYSTEM COSTS FOR A 540 MEGAGRAMS (600 TONS) PER HOUR MODEL PORTABLE PLANT

	Option I		Option II	
	Sand and Gravel	Crushed Stone	Sand and Gravel	Crushed Stone
1. Gas flowrate -				
A. Meters^3/minute	626	1,133	736	1,133
B. (ACFM)^a	(26,000)	(40,000)	(26,000)	(40,000)
2. Installed capital costs	$167,450	$237,670	$156,190	$234,640
3. Annualized costs -				
A. Annualized capital charges	$41,095	$58,330	$38,335	$57,580
B. Direct operating cost	24,186	34,878	23,060	34,575
C. Total	$65,281	$93,208	$61,395	$92,155
4. Cost effectiveness -				
A. $/megagram of particulate removed	$92	$86	$87	$85
B. ($/ton of particulate removed)	($84)	($78)	($79)	($77)

a - Actual Cubic Feet per Minute

TABLE 15

BAGHOUSE CONTROL SYSTEM COSTS FOR A
817 MEGAGRAMS (900 TONS) PER HOUR
MODEL PORTABLE PLANT

	Option I		Option II	
	Sand and Gravel	Crushed Stone	Sand and Gravel	Crushed Stone
1. Gas flowrate -				
A. Meters^3/minute	906	1,359	906	1,359
B. (ACFM)^a	(32,000)	(48,000)	(32,000)	(48,000)
2. Installed capital costs	$186,525	$262,345	$181,420	$258,985
3. Annualized costs -				
A. Annualized capital charges	$45,780	$ 64,380	$44,525	$ 63,555
B. Direct operating cost	27,541	40,404	27,030	40,068
C. Total	$73,321	$104,784	$71,555	$103,623
4. Cost effectiveness -				
A. $/megagram of particulate removed	$84	$80	$82	$80
B. ($/ton of particulate removed)	($77)	($73)	($75)	($72)

a - Actual Cubic Feet per Minute

and crushed stone industries. The cost-effectiveness ratios appearing in Tables 11 through 15 are simply the total annualized costs divided by the estimated amount of particulate collected per year.

A.3 ECONOMIC IMPACTS

A.3.1 Introduction and Summary

In order to further analyze the potential economic impacts of NSPS controls upon the portable plant segments of the crushed stone and sand and gravel industries, a Discounted Cash Flow (DCF) model was developed. This model has been used to estimate the financial status or profitability of portable plant operations, both before and after the addition of NSPS controls.

The model has recognized several major variations in the methods of operation chosen by various firms within the industry. For this reason separate analyses have been completed under different assumptions regarding:

- Portable plant capacity
- Average hours of operation per year
- Level of portable plant mobility, i.e., mobility among quarries alone, or both mobility among and within various quarry sites.

In the discussion which follows, those plants which typically move within the quarry (in order to minimize the distance between the primary crusher and newly blasted rock) are said to "follow the highwall", while those which remain stationary within each quarry are denoted as "no highwall". Sand and gravel plants were not examined under the "follow the highwall" option since this mode of operation is not used by such plants.

The results of the DCF analysis are summarized in Table 16. For those cases where the potential new investment is labled F (feasible), the economic feasibility of the investment will be unaffected by NSPS controls. Where NF (not feasible) is noted, the investment may not be made if the plant is to operate under the parameters specified. Where A (ambiguous) is noted, the DCF analysis has yielded "borderline" potential impacts for reasons discussed below. All assumptions made and steps taken in arriving at these conclusions are detailed in the sections which follow.

A.3.2 Methodology

The findings noted above have been derived through the application of a Discounted Cash Flow (DCF) model, constructed to reflect the financial situation of a given portable crushed stone or sand and gravel plant which may be purchased and operated in the future. The basic distinctions between fixed and portable operations have been considered in the development of this model. These distinctions include variations in equipment life, annual hours of operation, investment requirements, markets served, and the costs associated with the NSPS controls.

TABLE 16

SUMMARY OF DCF RESULTS FOR PORTABLE PLANTS

Plant Capacity Mg/hr	Plant Capacity tph	Operating Hours (hours/year)	Crushed Stone Uncontrolled	Crushed Stone With NSPS Controls No Highwall	Crushed Stone With NSPS Controls Follow Highwall	Sand and Gravel Uncontrolled	Sand and Gravel With NSPS Controls No Highwall
68	75	1250	NF	NF	NF	NF	NF
		1600	NF	NF	NF	NF	NF
135	150	1250	NF	NF	NF	NF	NF
		1600	A	NF	NF	A	NF
270	300	1250	A	NF	NF	A	NF
		1600	F	A	NF	F	A
540	600	1250	F	F	F	F	F
		1600	F	F	F	F	F

Key: F - economically feasible
NF - not economically feasible
A - ambiguous (investment not necessarily precluded)

All plants for which the DCF analysis has been applied have been assumed to function within a scenario defined by the following conditions:

- The plant will operate as a separate business entity or "profit center",

- The pass through of control costs to the consumers of the products of new portable plants is, to some extent, limited by competition of existing portable plants which will not be affected by the NSPS to the same degree,
- Individual plants may choose to operate either 1250 hours/year or 1600 hours/year,
- Individual plants may choose to remain stationary within each quarry (i.e., not follow the highwall) or move about within the quarry (i.e., follow the highwall),
- The planning horizon for potential investors in portable plants is 10 years.

The assumption that the new portable plant will operate as a separate business entity implies that the plant will not at any time be dependent upon, or supported by revenues generated by other business activities of the investing firm. It is implied therefore, that debt incurred through the initial investment, and all other expenses associated with the plant's operation will be paid only through those revenues generated by the new plant itself. This assumption may reflect a conservative point-of-view for vertically integrated or multi-plant firms; however, the assumption is plausible for horizontally integrated firms having a single processing plant.

The condition that the pass through of control costs to the consumers of portable plant products, will be limited by competition from existing portable plants (which will not be affected by NSPS), reflects the reality that portable plants typically compete with other portable plants, since the ability of a plant to locate near the site of an impending job, is the key to lowering customer transport costs and thus securing orders for crushed stone and sand and gravel. For stationary plants it has been projected that, due to the replacement of old plants by new (NSPS) plants, 25 percent of the cost of pollution control will be passed through every four years (see Section 8.4.2). Recognizing that the competition among portable plants is potentially greater, and thus the cost pass through ability lower, it has been assumed that portable plant operators will require twice as much time (i.e., eight years) to pass through 25 percent of pollution control costs. In the DCF analysis this level is reached by way of pass through increments of 6.25 percent every two years. This assumption is conservative in that for those sections of the country where competition is less intense, product prices may be increased sooner to reflect additional costs.

The DCF analysis detailed in Section A.3.3 has been constructed in such a way that the operational peculiarities of individual portable plant operators are considered. For example, it has been noted that the preferences of individual operators vary, especially with regard to the hours of operation per year and the movement of plants within individual quarries. Therefore, in an attempt to differentiate impacts for each of these modes of operation, each model plant has been individually examined assuming 1250 and 1600 operating hours per year, as well as preference for moving within individual quarries (i.e., following the highwall) or remaining stationary within each quarry (i.e., no highwall). It should be noted that the preference for within quarry mobility will entail higher pollution control costs due to the need to dismantle and set up control equipment more often.

The investment planning horizon of 10 years has been selected based upon the 10 year normal useful life of portable plants. The 10 year life has been supported by representatives of the industry.30

The cash flows considered by the DCF model are:

- Earnings after tax,
- Depreciation of plant and rolling stock,
- Depreciation of pollution control equipment,
- Working capital recovery,
- The salvage value of plant and rolling stock, and
- Payback of debt.

Earnings after tax have been determined after consideration of all operating costs, depreciation expenses, interest expenses, overhead, and pollution control costs. In the determination of earnings after tax the availability of depletion allowances and investment tax credits, have been recognized. Regarding depreciation, plant and rolling stock have been depreciated (straight-line) over their respective useful lives. Pollution control equipment has been depreciated over five years to a zero salvage value. It has also been assumed that working capital requirements are funded out of equity and that all plant and rolling stock is sold at salvage value after 10 years. Each of these items is discussed in greater detail in the following section.

A.3.2.1 Critical Elements. In the estimation of the potential impacts of NSPS controls, numerous data elements have been assembled and evaluated to allow their incorporation into the DCF model. In the descriptions listed below each of the critical elements is identified and discussed in terms of its use in the model. Sources of data pertinent to each critical element are listed in Section A.3.2.2.

With regard to operating hours per year, individual firms contacted[30] indicated a variety of preferences, however most tended toward two levels, 1250 and 1600 hours per year. Although the actual hours per year is heavily dependent upon the weather, these two figures have been identified as target levels. The number of operating hours per year is perhaps the most critical data element since it is the prime determinant of net revenues generated by each plant in this high fixed cost, low profit margin industry. In the DCF model all production is assumed to be sold and thus there is no net change in the inventories of the model plant.

Concerning product prices, distinctions between crushed stone and sand and gravel have been made. The values employed in the DCF model are \$3.25/ton for crushed stone and \$2.86/ton for sand and gravel. The price of crushed stone was noted by two industry representatives and the price of sand and gravel was derived from the crushed stone price, based upon Bureau of Mines[31,32] data indicating that for recent years the price of sand and gravel has approached 88 percent of that for crushed stone.

Based upon the \$3.25/ton price of crushed stone, operating costs (excluding depletion, depreciation, interest and overhead) have been identified based on discussion with industry representatives, as \$2.10/ton. Operating costs for sand and gravel plants have been estimated by applying the ratio of operating cost/price for crushed stone (\$2.10/\$3.25), to the price of sand and gravel, to estimate sand and gravel operating costs of \$1.85/ton.

The validity of the \$2.10 and \$1.85/ton operating cost levels for crushed stone and sand and gravel portable plants, respectively, has been supported through the determination of the pre-control Internal Rates of Return (IRR) for those plants faced by these costs. Such rates have been calculated and are summarized in Table 17.

TABLE 17

INTERNAL RATES OF RETURN FOR PORTABLE CRUSHED STONE AND SAND AND GRAVEL PLANTS

(Pre-Pollution Control)

Plant Capacity (Mg/hr)	Plant Capacity (tph)	Operating Hours (hours/year)	Crushed Stone	Sand and Gravel
68	75	1250	<10.0%	<9.9%
		1600	10.0%	9.9%
135	150	1250	10.1%	10.2%
		1600	14.0%	14.3%
270	300	1250	14.2%	14.5%
		1600	18.2%	18.4%
540	600	1250	20.9%	21.4%
		1600	25.6%	>21.4%

The IRR percentages in Table 17 appear to be reasonable in light of current returns on other forms of long-term investment. Had the pre-control rates been higher than those actually calculated, the understatement of operating costs could be a suspected cause. On the other hand, if the pre-control rates were estimated to be lower than those of Table 17, the overstatement of operating costs/ton might have been suspected.

Depreciation of plant equipment has been taken as straight-line over its 10 year life. Depreciation of rolling stock has been taken as straight-line over a seven year life in order to take full advantage of the investment tax credit. Depreciation of pollution control equipment has been taken as straight-line over five years to a zero salvage value. Investment tax credit is also available, and is taken on pollution control equipment using a 5-year rapid amortization writeoff.

Debt terms for plant, rolling stock, and pollution control equipment have been assumed to be five years at a 15 percent interest rate. Industry contacts have noted that the availability of debt financing at terms better than those noted, would be uncommon. It should be noted that the results of the DCF model are not sensitive to variation of the interest rate.

The financing of portable equipment in terms of debt/equity has been observed to range from 0 percent to 100 percent, dependent upon the preferences and abilities of individual firms. For purpose of the DCF model a ratio of 50/50 is employed. The use of this ratio has been judged realistic by industry representatives. It should be noted that the results of the DCF model are not sensitive to variation in the debt/equity ratio over the 0 to 100 percent range.

With regard to overhead expenses of portable plant operations, industry sources have indicated that for a 270 Mg/hr (300 tph) portable plant such costs would be about $.25/ton for each ton of crushed stone produced. For the 540 Mg/hr (600 tph) plants this figure has been reduced to $.22/ton due, for the most part, to economies of scale. These figures have been employed for both crushed stone and sand and gravel plants.

Pollution control costs for purposes of the DCF analysis, have been grouped into four basic classes:

- Excess moving costs,
- Annual Cost of operation and maintenance,
- Depreciation, and
- Interest on borrowed capital used to purchase and install pollution control equipment.

The inclusion of excess moving costs account for those added costs incurred due to the need to dismantle, move and set up the pollution control system each time the portable plant is moved, regardless of whether the move is within the quarry or to another quarry. The costs associated with these activities are summarized in Table 6, while their inclusion into the DCF model is described in Section A.3.3. Regarding the number of moves made by the typical portable plant, industry sources have indicated that the typical portable plant moves to a different quarry, on average, four times each year.[30] For those plants which prefer to follow the highwall, an average of 24 such within-quarry moves might be made. Sand and gravel plants, on the other hand, do not often move within the gravel pit, since very little blasting is done.

The annual cost category represents the annual total of pollution control costs incurred by each model plant. The costs summarized under this heading include annual maintenance and operating costs, utilities, filter replacement, dust disposal costs, property taxes, insurance, and administrative expenses.

Depreciation of pollution control equipment is taken over a 5 year useful life, with a zero salvage value. For those plants which choose to follow the highwall, the cost of a small crane (needed to facilitate dismantling and reconnecting of pollution-control equipment) has been added to the plant costs, and is thus depreciated over ten years. (Plant investment costs are summarized in Section A.3.2.3.)

Interest on the pollution control equipment for each plant has been determined by calculating the annual interest-principal repayment schedule according to the debt terms described above.

Depletion expenses have been determined for each model plant, under the assumption that the quarry site is leased rather than owned by the portable plant operator. Under these circumstances the operator is entitled to a depletion allowance according to a depletion base defined as:

Depletion base = price/ton - royalty/ton.

Industry representatives have noted that royalties paid by portable plant operators are typically 5 percent of the sale price per ton. In the DCF model the annual depletion allowance is calculated as:

Depletion = depletion base x annual output x % depletion.

The Internal Revenue Code allows percentage depletion for both crushed stone and sand and gravel minerals of five percent. Two limitations to the use of percent depletion are:

- The maximum depletion claimed in any year cannot exceed one-half of that year's earnings before tax, and
- Depletion is subject to minimum tax as a tax preference item.

These limitations have been included, where appropriate, in the year-by-year calculations of the DCF model. The assumption that the owner must pay royalties represents a conservative point of view, since this slightly reduces the available depletion base.

Regarding the Federal tax rate, the marginal tax rate can vary up to a maximum of 46 percent of earnings before tax and after depletion. In the DCF model it is assumed that taxable income of the firm, resulting from other activities, is sufficiently greater than $100,000 annually, and thus the tax rate employed is 46 percent. State taxes are assumed to be 5 percent of earnings before tax since this is the most common state tax rate.

Working capital or capital required to finance accounts receivable and inventories have been considered in the DCF models. Industry contacts[30] have noted that both accounts receivable and inventories each require capital financing on the level of 15 percent of sales, giving total working capital requirements of 30 percent of sales. In the DCF models it has been assumed that working capital is financed from equity and that all working capital is recovered after the tenth year.

Salvage values of plant and rolling stock have been considered in the DCF model as cash inflows resulting from their sale in the tenth year. The salvage values have been determined through industry contacts as well as inspection of the used equipment markets as defined by industry trade journals.[33] The salvage value factors used in the DCF model are 36 percent for plant and equipment and 16 percent for rolling stock.

The model assumes that firms will take maximum advantage of the investment tax credit. It is recognized that the credit cannot exceed 10 percent of the investment and may not be carried forward more than seven years.

A.3.2.2 Sources of Data. Sources of data used in the DCF analysis are noted in Table 18.

A.3.2.3. Plant Investment. Estimates of the costs of new portable crushed stone and sand and gravel plants were assembled after discussion with both the manufacturers of portable plants[34] and firms who use portable equipment in their quarrying activities. On the basis of these discussions the investment levels noted in Table 19 were developed and used in the DCF model. In those instances where a small crane is purchased, in order to maintain within-quarry mobility, the cost of such a crane is assumed to be $80,000.

Plant and equipment investment for the 270 Mg/hr (300 tph) sand and gravel plant was determined by noting the difference in equipment requirements (and thus costs) between the 270 Mg/hr (300 tph) crushed stone model plant and the sand and gravel model plant of the same capacity. Plant and equipment investments for the 68, 135 and 540 Mg/hr (75, 150 and 600 tph) plants were estimated through the .6 power capacity rule.

TABLE 18

SOURCES OF DATA

Data Element	Source Bureau of Mines	Federal Reserve Bank	1979 U.S. Master Tax Guide	Robert Morris Associates	"Highway and Heavy Construction"	Section A.2	Iowa Manufacturing Company	Industry Representatives
Operating Hours/Year								X
Product Prices	X							X
Operating Costs								X
Depreciation			X					X
Debt Terms		X						X
Debt/Equity								X
Overhead								X
Pollution Control Costs						X		
Moves/Year							X	X
Depletion			X					X
Tax Rates			X					X
Investment Tax Credit			X					X
Working Capital				X				X
Salvage Values					X		X	X
Plant Investment							X	X

TABLE 19

REQUIRED INVESTMENT FOR NEW PORTABLE CRUSHED STONE AND SAND AND GRAVEL PLANTS

($1,000's 1979)

Plant Capacity		Crushed Stone			Sand and Gravel		
Mg/hr)	(tph)	Plant and Equipment	Rolling Stock	Total Investment	Plant and Equipment	Rolling Stock	Total Investment
68	75	305	217	522	213	218	431
135	150	462	330	792	323	330	653
270	300	700	500	1200	490	500	990
540	600	1061	758	1819	743	758	1501

A.3.3 Discounted Cash Flow (DCF) Analysis. Table 20 presents an example of the data sheets which were developed for each model plant under the previously discussed scenarios regarding operating hours and plant movements. The example presented in Table 20 is that for the 270 Mg/hr (300 tph) crushed stone plant which operates at 1,600 hours per year and prefers to maintain its mobility within the quarry (i.e., follow the highwall). In this case the total investment required (excluding pollution control) is $1,748,000 represented by:

	Cost	Source of Funds
Plant	$700,000	50% debt, 50% equity
Small Crane	80,000	-do-
Rolling Stock	500,000	-do-
Working Capital	468,000	100% equity
Total Investment	$1,748,000	

TABLE 20

EXAMPLE DISCOUNTED CASH FLOW ANALYSIS ($000)

	YEAR	1	2	3	4	5	6	7	8	9	10
1.	REVENUE	1,560	1,560	1,560	1,560	1,560	1,560	1,560	1,560	1,560	1,560
2.	Operating Costs: Plant & Rolling Stock	1,016	1,016	1,016	1,016	1,016	1,016	1,016	1,076	1,076	1,076
3.	Depreciation: Plant	49	49	49	49	49	49	49	49	49	49
4.	Depreciation: Rolling Stock	60	60	60	60	60	60	60	-	-	-
5.	Interest: Plant & Rolling Stock	96	82	65	46	24	-	-	-	-	-
6.	Overhead	120	120	120	120	120	120	120	120	120	120
7.	Total Cost: Plant Production (2+···+6)	1,341	1,327	1,310	1,291	1,269	1,245	1,245	1,245	1,245	1,245
8.	Excess Moving Cost: Pollution Control	61	61	61	61	61	61	61	61	61	61
9.	Annual Cost: Pollution Control	38	38	38	38	38	38	38	38	38	38
10.	Depreciation: Pollution Control	40	40	40	40	40	-	-	-	-	-
11.	Interest: Pollution Control	30	26	21	15	8	-	-	-	-	-
12.	Total Cost: Pollution Control (8+···+11)	169	165	160	154	147	99	99	99	99	99
13.	Pass Through: (12x% pass through)	0	0	10	10	18	12	19	19	25	25
14.	TOTAL COST: [(7+12)-13)]	1,510	1,492	1,460	1,435	1,398	1,332	1,325	1,325	1,319	1,319
15.	EARNINGS BEFORE INCOME TAX: (1-14)	50	68	100	125	162	228	235	235	241	241
16.	Depletion	25	34	50	63	73	73	73	73	73	73
17.	Earnings Before Tax and After Depletion (15-16)	25	34	50	62	89	155	162	162	168	168
18.	Federal Tax Liability	12	16	23	29	41	72	75	75	77	77
19.	Investment Tax Credit	12	16	23	29	39	29	0	-	-	-
20.	Federal Tax: (18-19)	0	0	0	0	2	43	75	75	77	77
21.	Adjustment: Minimum Tax	10	10	10	10	10	43	-	-	-	-
22.	Minimum Tax Base: (16-21)	15	24	40	53	63	30	-	-	-	-
23.	Minimum Tax	2	4	6	8	9	5	-	-	-	-
24.	Total Federal Tax: (20+23)	2	4	6	8	11	48	75	75	77	77
25.	State Tax	3	3	5	6	8	11	12	12	12	12
26.	TOTAL TAX: (24+25)	5	7	11	14	19	59	87	87	89	89
27.	EARNINGS AFTER TAX: (15-26)	45	61	89	111	143	169	148	148	152	152
28.	Depreciation: Plant	49	49	49	49	49	49	49	49	49	49
29.	Depreciation: Rolling Stock	60	60	60	60	60	60	60	-	-	-
30.	Depreciation: Pollution Control	40	40	40	40	40	-	-	-	-	-
31.	Total Depreciation: (28+29+30)	149	149	149	149	149	109	109	49	49	49
32.	Working Capital Recovery	-	-	-	-	-	-	-	-	-	468
33.	Salvage Value	-	-	-	-	-	-	-	-	-	368
34.	Principal Repayment: Plant & Rolling Stock	95	109	125	144	166	-	-	-	-	-
35.	Principal Repayment: Pollution Control	30	35	40	46	53	-	-	-	-	-
36.	Total Principal Repayment: (34+35)	125	144	165	190	219	-	-	-	-	-
37.	NET CASH INFLOW: (27+31+32+33-36)	69	66	73	70	73	278	257	197	201	1,037
38.	Discount Factor	.870	.756	.658	.572	.497	.432	.376	.327	.284	.247
39.	DISCOUNTED CASH FLOW: (37x38)	60	50	48	40	36	120	97	64	57	256

$\sum_{1}^{10} DCF = \$828,000$

Compared To

EQUITY = $1,108,000

Key:
0 = calculated value
- = calculation not applicable

Since the plant, crane and rolling stock are financed 50/50 debt/equity, and working capital from equity alone, the total investment from equity is $1,108,000.

The steps summarized below detail how the discounted cash flows for the ten year life of this plant were determined. The derivation of individual values are explained in Section A.3.2.1.

- Row 1, Revenue, was determined by multiplying operating hours per year (1,600) by the capacity per hour (300 tph) and the price per ton for crushed stone ($3.25).
- Row 2, Operating Costs: Plant and Rolling Stock, has been estimated by multiplying operating hours per year (1,600) by the capacity per hour (300 tph) and the operating costs per ton ($2.10). In addition $8,000/ year was included as the operating costs for the small crane.
- Row 3, Depreciation: Plant, was derived by subtracting from the total investment in plant ($700,000 + $80,000), the estimated salvage value at 36 percent ($281,000) and calculating the annual depreciation charge for each of the 10 years.
- Row 4, Depreciation: Rolling Stock, was determined by subtracting from the investment ($500,000) its salvage value of 16 percent ($80,000) and calculating the annual depreciation charge for each of seven years. For years 8, 9 and 10, the model assumes the fully depreciated rolling stock requires increased maintenance and so operating costs have been increased by $60,000 (i.e. the value of annual depreciation) for those years (Row 2).
- Row 5, Interest: Plant and Rolling Stock for each year has been determined by calculating the annual interest-principal repayment schedule based on the terms of a five year loan of $640,000 at 15 percent.
- Row 6, Overhead, has been determined by multiplying the operating hours per year (1,600) by the capacity per hour (300 tph) and the estimated overhead costs per ton ($.25).
- Row 8, Excess Moving Costs: Pollution Control have been estimated based upon the data summarized in Table 6 regarding the cost of

moving the control system. Based upon an estimated 24 moves/year within the quarry, 4 moves/year among quarries, labor costs for control system dismantling and set up of $1,440/move and average transportation costs of $5,120 for moves to different quarries, the annual excess moving costs have been determined to be $61,000.

- Row 9, Annual Cost: Pollution Control was obtained by summing the following annual direct cost components (Table 13): annual O &M costs, utilities, filter replacement, dust disposal, and taxes, insurance and administration.
- Row 10, Depreciation: Pollution Control, was determined by assuming the total installed capital costs ($203,600) of Table 13 will be depreciated to zero salvage value over five years.
- Row 11, Interest: Pollution Control, was determined through the interest-principal repayment schedule for a loan of ($203,600) for five years at 15 percent.
- Row 13, Pass-through, was determined based on the assumptions regarding the gradual pass-through of pollution control costs to the consumers of crushed stone and sand and gravel (see Section A.3.2). More specifically, the DCF model assumes that the following percentages of the total costs of pollution control will be passed to consumers in the form of higher prices:
  - Years 1 and 2 = 0 percent
  - Years 3 and 4 = 6.25 percent
  - Years 5 and 6 = 12.50 percent
  - Years 7 and 8 = 18.75 percent
  - Years 9 and 10 = 25.00 percent

  While in reality the pass through of control costs will increase the yearly revenues, the arithmetic of Table 20 is based upon the deduction of the pass through amounts from total costs.
- Row 16, Depletion, has been estimated for each year by multiplying the depletion base ($3.08), the calculation of which is described in Section A.3.2.1, by the capacity per hour, operating hours per year, and the five percent depletion allowance. Following this procedure has yielded a maximum annual depletion of $73,000. However, Federal tax laws prohibit the claiming of depletion allow-

ances in excess of one-half of earnings before tax. In the case presented in Table 20 the plant cannot claim full depletion until the fifth year of operation.

- Row 18, Federal Tax Liability, has been calculated on the basis of a marginal tax rate of 46 percent.
- Row 19, Investment Tax Credit, has been calculated on the assumption that the firm will attempt to apply the full credit available, which in this case is $148,000 (i.e., 10 percent of the total investment of $1,483,600 including pollution control). Current tax laws dictate that credit may be taken on the first $25,000 of earnings before tax and after depletion, plus a percentage of earnings above this amount. Presently the tax laws allow credit for 60 percent of earnings above the $25,000 level in 1979, and 70 and 80 percent for 1980 and 1981, respectively. For 1982 and all following years the percentage is 90 percent.
- Row 21, Adjustment: Minimum Tax. Since the previously discussed depletion allowance is a "tax preference item" the tax law calls for the payment of a minimum tax if the amount of the firm's Federal tax (row 20) is less than the depletion claimed (row 16). For those years which this is so, an adjustment of the year's depletion must be made in order to define a "minimum tax base" (row 22). This adjustment is taken as the years Federal tax (row 20) unless that tax is less than $10,000 in which case the adjustment is $10,000 according to the Internal Revenue Code.
- Row 22, Minimum Tax Base, was determined by subtracting the adjustment (row 21) from the year's depletion (row 16).
- Row 23, Minimum Tax, was determined by applying the minimum tax rate of 15 percent, to each year's minimum tax base (row 22).
- Row 24, Total Federal Tax, was derived through the addition of each year's minimum tax (row 23) and Federal tax (row 20).
- Row 25, State Tax, was determined through the application of the most common state tax rate (5 percent) to each year's earnings before income tax (row 15).
- Row 26, Total Tax, shows the amount of Federal and state taxes payable for a particular year.

- Row 27, Earnings After Tax, forms the first item in the cash flow calculations (Rows 27 through 37).
- Rows 28, 29, and 30, entail the "adding back" of various depreciation amounts into the annual cash flows of the portable plant.
- Row 32, Working Capital Recovery, was added to the final year's cash flow to reflect the recovery of equity capital previously sunk in accounts receivable and inventories.
- Row 33, Salvage Value, was added to the tenth year's cash flow to reflect cash generated from the sale of the ten year old portable plant. The calculation of this salvage value was noted previously in Section A.3.2.1.
- Row 34, Principal Repayment: Plant and Rolling Stock, was deducted from each of the first five year's cash flows since one-half of the investment in plant and rolling stock has been financed through debt over five years at 15 percent.
- Row 35, Principal Repayment: Pollution Control, was also deducted from the cash flows of years one through five since the investment in pollution control equipment has been financed completely through debt over five years at 15 percent.
- Row 38, Discount Factor. In order to account for the fact that cash flows to be received during the near future are "more valuable" to the firm than those to be generated in the later years, all cash flows have been discounted to their present value. The discount factors have been determined on the basis of a cost of equity of 15 percent. The cost of equity has been used since the DCF analysis detailed above has accounted for the repayment of all loans (i.e., debt) used to support the portable plant's operation.
- Row 39, Discounted Cash Flow. When the cash flows of each year are discounted to their present value and summarized a value of $828,000 is derived. It is this value which is compared to the original investment from equity ($1,108,000) to allow the further calculation of the Internal Rate of Return (IRR) as described below.

A.3.4 Conclusions

A.3.4.1 Internal Rates of Return. In an effort to gain greater insight into the specific economic impacts upon those plants examined, the Internal

Rate of Return (IRR) for each plant was determined. Such a rate is defined, in each instance, as that rate of return which equates the present value of future cash flows with the value of the initial required investment from equity. Therefore, according to this definition, the feasibility of individual investments is judged by whether or not the IRR is greater than the cost of equity (and thus economically attractive) or less than the cost of equity (and thus not attractive). Based on discussions with industry representatives, the cost of equity was assigned a value of 15 percent per year.

A.3.4.2 Feasibility Definitions. Once each IRR was identified it became necessary to establish boundaries or "cut-off" points so that economically feasible and non-feasible investments might be more clearly distinguished. While in the strictest sense, such a cut-off point should be the cost of equity, a middle range of "ambiguous" results has been selected. The need for such a range is based upon the reality that the economic environment of all portable plants is not, and will not be identical. Recognizing this reality, the values for a number of parameters chosen in the above DCF analysis have reflected conditions which would be faced by a small number of plants in the extreme. Recognition of the use of such conservative assumptions is crucial in the interpretation of the DCF results (Table 16) since, in reality, many plants will not face conditions of such an unfavorable nature.

Specific examples of the use of conservative assumptions made in this analysis include:

- Operating hours per year - it is quite possible that the plants in question can or will operate for a number of years during the 10-year span at rates higher than 1,250 hours per year,
- Prices - control costs may be passed to the consumer at a rate much higher than that assumed, especially in those areas of less strict competition,
- Debt terms - some firms, especially those with well established credit lines, may be able to obtain bank financing at less than 15 percent, or over periods longer than 5 years.

For these reasons a range of ambiguity of 12 to 15 percent IRR has been selected, and for the purpose of Table 16, NSPS controls for those plants whose post-control IRR is greater than 15 percent are identified as "economically feasible", while those below 12 percent are said to be "not economically feasible". For a specific plant whose internal rate of return, as calculated by the method employed here, falls within the 12 to 15 percent range (termed "ambiguous"), an investment decision will have to be made after careful reevaluation of prevailing process, market and economic conditions.

A.3.4.3 Adaptation of Portable Plants to NSPS Control. In general, the implications of the results of the DCF analysis summarized by Table 16 are that the profitability of those new plants who desire to operate at relatively low hours per year and/or maintain within quarry mobility will be adversely affected. With specific regard to crushed stone, it appears that the new 270 Mg/hr (300tph) portable plants may be forced to operate at a greater number of hours each year and limit the number of within quarry moves made. However, it should be noted that for those new plants which can operate at levels above 1,250 hours per year and also pass a greater portion of control costs to consumers of crushed stone, profitability will be maintained. Since sand and gravel plants ordinarily do not move within gravel pits, the new 270 Mg/hr (300 tph) portable plants which will maintain profitability will be those which either operate at a higher level of hours each year, or can increase the price of their products enough to cover the increased costs of pollution control.

REFERENCES

1. Letter and attachments from Brown, Howard, Iowa Manufacturing Company, to Viconovic, George, GCA/Technology Division. June 18, 1979. Data on portable and stationary plants in the crushed stone and sand and gravel industries.

2. Telecon. Hart, Michael, Colorado Sand and Gravel Association with Viconovic, George, GCA/Technology Division. June 13, 1979. Portable plants in the sand and gravel industry.

3. Telecon. Davidson, Edward, National Sand and Gravel Association with Viconovic, George, GCA/Technology Division. June 13, 1979. Portable plants in the sand and gravel industry.

4. Telecon. Hoover, Earl, United States Bureau of Mines with Viconovic, George, GCA/Technology Division. June 8, 1979. Portable plants in the crushed stone industry.

5. Telecon. Renninger, Frederick, National Crushed Stone Association with Viconovic, George, GCA/Technology Division. June 13, 1979. Portable plants in the crushed stone industry.

6. Telecon. Pressler, J., United States Bureau of Mines with Viconovic, George, GCA/Technology Division. June 8, 1979. Portable plants in the gypsum industry.

7. Telecon. Messinger, Arthur, United States Bureau of Mines with Viconovic, George, GCA/Technology Division. June 8, 1979. Portable plants in the pumice industry.

8. Telecon. Ampian, S., United States Bureau of Mines with Viconovic, George, GCA/Technology Division. June 11, 1979. Portable plants in the clays industry.

9. Telecon. Brown, Howard, Iowa Manufacturing Company with Viconovic, George, GCA/Technology Division. June 11, 1979. Portable plant industry data.

10. Telecon. Brown, Howard, Iowa Manufacturing Company with Viconovic, George, GCA/Technology Division. June 15, 1979. Industry data.

11. Telecon. Hart, Michael, Colorado Sand and Gravel Association with Viconovic, George, GCA/Technology Division. June 18, 1979. Industry data.

12. Telecon. Olson, Del, Gifford-Hill Company with Viconovic, George, GCA/Technology Division. June 28, 1979. Industry data.

13. Telecon. Cole, Richard, Flintkote Company with Harnett, William, GCA/ Technology Division. November 8, 1979. Portable plant operating and movement data.

14. Telecon. Brown, Howard, Iowa Manufacturing Company with Viconovic, George, GCA/Technology Division. June 21, 1979. Portable and stationary plant sales data.

15. U.S. Bureau of Mines Mineral Commodity Summaries 1979. Washington, D.C., U.S. Department of the Interior, 1979. 190 p.

16. Telecon. Cole, Richard, Flintkote Company with Viconovic, George, GCA/Technology Division. June 13, 1979 and June 14, 1979. Portable plant cost and movement data.

17. Telecon. Olson, Del, Giffor-Hill company with Viconovic, George, GCA/Technology Division, June 15, 1979. Portable plant cost and movement data.

18. Telecon. Hart, Michael, Colorado Sand and Gravel Association with Viconovic, George, GCA/Technology Division. June 17, 1979. Portable plant movement data.

19. Telecon. Lahu, Peter, Speer Construction with Viconovic, George, GCA/Technology Division. July 17, 1979. Portable plant operating and movement data.

20. Telecon. Ellis, Oscar, Moline Consumers Company with Viconovic, George, GCA/Technology Division. July 18, 1979. Portable plant operating and movement data.

21. Telecon. Hart, Michael, Colorado Sand and Gravel Association with Viconovic, George, GCA/Technology Division. July 19, 1979. Portable plant operating and movement data.

22. Telecon. Ellis, Oscar, Moline Consumers Company with Harnett, William, GCA/Technology Division. November 8, 1979. Portable plant operating and movement data.

23. Letter and attachments from Schroeder, Philip N., M.C. Schroeder Company to Viconovic, George, GCA/Technology Division. July 27, 1979. Baghouse cost data.

24. Letter and attachments from Meyer, Robert J., Joy Industrial Equipment Company-Western Precipitation Division to Viconovic, George, GCA/Technology Division. July 27, 1979. Baghouse cost data.

25. Telecon. Schroeder, Philip N., M.C. Schroeder Company with Viconovic, George, GCA/Technology Division. August 6, 1979. Ductwork cost data.

26. Telecon. Hamlin, Robert, Hamlin Sheet Metal Company with Viconovic, George, GCA/Technology Division. August 8, 1979. Ductwork cost data.

27. PEDCo. Environmental Inc. Cost Analysis Manual for Standards Support Document. Cincinnati, PEDCo. Environmental Inc., April 1979. 82 p.

28. Perry, Robert H. and Cecil H. Chilton. Chemical Engineers' Handbook. New York, McGraw-Hill Book Company, 1973.

29. Memo from Brown, Howard, Iowa Manufacturing Company, to Goodwin, Don, EPA/OAQPS. March 1, 1979. Data on portable plants and stationary plants in the crushed stone and sand and gravel industries.

30. Included among industry contacts are;

    - Douglas E. Anderson, B.L. Anderson, Inc., Cedar Rapids, Iowa
    - Larry Hinton, Azrelli Construction, Inc., Kankakee, Illinois
    - Floyd Lillig, Iowa Manufacturing Company, Cedar Rapids, Iowa
    - William J. Paxson, Chief Engineer, Iowa Manufacturing Co., Cedar Rapids, Iowa
    - Albert Richardson, Gordon Quarries, Inc., Forrest City, Missouri
    - Howard L. Slife, V.P., Cedar Rapids Aggregate Equipment Sales, Iowa Manufacturing Co., Cedar Rapids, Iowa
    - Robert Treager, Farmers Stone and Treager Quarries, Inc., Chiliglafi, Missouri

31. U.S. Bureau of Mines Mineral Commodity Profiles Stone. MCP-17. U.S. Department of the Interior, Washington, D.C. July 1978. p.16

32. U.S. Bureau of Mines. Mineral Commoidity Profiles. Sand and Gravel. MCP-23. U.S. Department of the Interior. Washington, D.C. September 1978. p.12

33. Highway and Heavy Construction. September 1979. p. 150-158.

34. Iowa Manufacturing Company. Cedar Rapids. Iowa